U.S. DEPT. OF AGRICULTURE
FOREST SERVICE

COLD TOLERANCE of GUAYULE

1946

EMERGENCY RUBBER PROJECT

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COLD TOLERANCE OF GUAYULE //

By

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UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

EMERGENCY RUBBER PROJECT

September 1946

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E.C.T. 4-24-46

NATIVE HABITAT OF GUAYULE

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INTRODUCTION

This report is simply a record of the observations that were made during a three year period on the reaction of guayule to cold test plantings* of guayule in Texas and New Mexico. The data are compiled for purposes of making the information accessible for future reference.

Research in the domestication of guayule had gone on for about thirty years prior to the war, but because most of this work had been carried on in the warmer areas of California and Arizona, there was little opportunity to learn the shrub's reaction and limitations to a low temperature environment.

Guayule is a highly specialized plant in that it is a product of an unique set of environmental conditions that make its native habitat. Here it endures high temperatures, abides long periods of drouth, and tolerates sub-freezing intrusions of cold without apparent injury. Yet upon the advent of wet years, which irregularly appear in most desert environments, it will respond quickly with a luxuriant growth, only to sink once more into semi-dormancy when the drouth returns.

The shrub appears particularly specific in its soil environment requirements. It follows along soils with certain physical characteristics, yet refuses to penetrate into adjacent areas which are generally considered more favorable to plant life and on which species associated with guayule thrive much better. In the northern limits of its distribution, guayule does not appear to be greatly injured by temperatures of 5 degrees F. or an occasional zero, yet under cultivation it is sometimes severely injured by only a few degrees of frost and may be totally killed by five to zero degrees temperature.

FACTORS OF THE NATIVE ENVIRONMENT

A brief summary of the factors operating in the native environment are given for the interpretive light they may throw on the behavior of the domesticated plant.

In its natural distribution, guayule is confined to certain areas of the Chihuahuan desert in north Central Mexico and the Big Bend of Texas. Lloyd (6) estimated the general range of the plant to comprise about 130,000 square miles with guayule actually occupying about ten percent of this area. Whatever this area was at the time Lloyd made his studies in 1907 and 1908, no doubt the net guayule area is now smaller due to the great amount of shrub that has been harvested. Grazing by sheep is reported as a factor which in recent years is killing out many good stands of the plant. (3).

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* These plantings, known as indicator plots, were small test plantings usually about one acre in size located and supervised by the Bureau of Plant Industry, Soils, and Agricultural Engineering as a part of its research program of the Emergency Rubber Project.

As compared to the entire range only a small proportion of the guayule area occurs in Texas, but its occurrence here is important (a) because it is the only native stand in the United States, and (b) is the most northern extension of the plant's habitat. This northern boundary falls along an irregular east-west line from about 20 miles east of Balmorhea in Reeves County, eastward to Ft. Stockton and then along a northward bulging arc to the vicinity of Bakersfield in southeast Pecos County. There is another stand to the south in Terrell County near Dryden. The Dryden shrub appears to be the most easterly extent of guayule in Texas. Although the plant has been reported near Langtry in southwest Val Verde County, this stand was never found and verified. It may have disappeared due to grazing.

The elevation of the guayule region, as a whole, ranges from 2,000 to 10,000 feet with comparatively few large stands above 6,500 feet. In Texas the elevation range of the plant is between the 2,800 and 4,200 feet, with the bulk of the stands falling between the 2,800 to 3,800 foot levels. The most extensive guayule area in Texas is on and near the O-Two Ranch about 30 miles south of Alpine, where the average elevation is about 3,700 feet.

The native sites of guayule are largely confined to the relatively deep, highly calcareous soils of colluvial slopes, alluvial fans, and high undulating benches where the soil is sufficiently coarse to have a good infiltration capacity and good internal drainage. The valley lands of the guayule country have fine, tight soils. The plant rarely, if ever, penetrates into these valleys, but usually feathers out abruptly at the foot of the slopes.

Along the plant's northern periphery in Reeves and Pecos Counties guayule is confined mainly to the stony, steep slopes of the buttes and escarpments on the higher lying levels of the Edwards Plateau. Here, as elsewhere, it does not penetrate the wide intervening plains and valleys.

Climatological data for the guayule area as a whole are scarce, the available records are intermittent and usually of short duration. There is a particular scarcity of records for the Mexican areas. Several investigators, however, who have surveyed and studied the plant in Mexico, have gathered considerable material (4), (6) from which a rather definite picture can be drawn.

The mean annual rainfall varies greatly, from 7 to 15 inches, depending on elevation and the proximity of high mountains. It fluctuates even more widely from year to year and ranges from an extreme low of 2 inches at Presidio, Texas to an extreme high of 32 inches as at Ft. Stockton. The extremes frequently fall in wet or dry cycles of three or more years duration.

The following table illustrates the variability of rainfall in the Big Bend guayule region. The figures should not be considered as dependable for long time averages for with one exception the records are short and oftentimes are not consecutive for the periods indicated.

RAINFALL IN THE BIG BEND AREA OF TEXAS

U. S. Weather Station	Years of Record	Extreme Annuals		Period Average
		Maximum	Minimum	
		Inches		Inches
Alpine	21	33	10	16
Balmorhea	21	28	4	14
Ft. Stockton	64	33	4	15
Marathon	15	29	8	18
Marfa	9	19	5	12
Presidio	18	23	2	10
O-Two Ranch (1914-1928)	15	25	4	14
Sanderson	9	23	7	13

It is apparent from such records as are available that guayule not only endures single years of drouth, but can exist through cycles of three or more years during which every year is much below normal. Furthermore, the rainfall is seasonal with most of it falling during the six months from May to October, 76 percent at Ft. Stockton and 79 percent at the O-Two Ranch. Cooperrider and Culley (3) reported about 90 percent of the rainfall as occurring from June to October in the guayule areas of Mexico. They also state that during the dry season the rains rarely amount to more than a quarter of an inch and usually are more traces.

But the water requirements of guayule cannot be gauged in terms of rainfall alone since the plant most frequently occurs on coarse, permeable soils which are usually deep and near the base of mountains or higher lying elevations from which there is considerable run-off. On relatively level areas, where the plant is sometimes found, there is probably little or no run-off because of the physical character of the soil. Also, the plants here may have access to supplemental moisture from underground sources.

Guayule is known to have a deep rooting system. Muller (7) found that guayule roots penetrate from 12 to 18 feet in from 1 to 2 years where soil conditions are favorable. The plant appears to utilize soil moisture from these lower levels rather slowly, but obtains sufficient deep soil moisture to tide the plant through periods of drouth.

The peak of the season's rainfall in the native range occurs during August and September, the amount that falls during the dry season is insufficient to stimulate much vegetative growth. The reaction of guayule is to spring into quick growth and full bloom immediately following a heavy rain, utilize the moisture in the upper soil levels rather rapidly and pass into a semi-dormant or dormant condition depending on the degree of depletion of available soil moisture. This process repeats itself throughout the growing season whenever moisture conditions are right and ceases only when temperatures become too low for plant growth. It will

be noted, however, that approach of the winter season is the time when the plant is normally dormant (at least in the majority of years) due to reduced moisture supply.

Temperatures vary with latitude, altitude and season. Also there are marked diurnal fluctuations of temperatures which are common to all parts of the guayule area and to all seasons of the year. With the guayule sites occurring on the foot slopes between the mountains and the valleys, maximum and minimum temperatures are rarely constant for more than minutes, but are on the move upward or downward due to the cool air drainage from the mountains or ascending warm air currents.

Maximum temperatures of above 100 degrees F. are frequent during the summer months in most of the natural range. The absolute maxima recorded from all stations range from 95 degrees to 122 degrees F. (9). Temperatures above 100 degrees F., however, are rarely of long duration, often not in excess of one hour.

As nearly as can be determined from available data it appears that maximum temperatures of 120 degrees F. may occur occasionally in most of the guayule areas of Mexico. Freezing temperatures are seldom of long duration. The coldest temperatures in the native habitat occur along the northern periphery where a minus 9 degrees at Balmorhea and a minus 7 degrees at Ft. Stockton have been recorded. Zero or below has been recorded four times at Ft. Stockton. The following table gives the absolute maxima, minima, mean, and the annual mean minima for seven Weather Bureau stations in the Big Bend country.

TEMPERATURES IN THE BIG BEND AREA

Station	Years of Record	Absolute Maximum degrees F.	Absolute Minimum degrees F.	Mean	Annual Mean Minimum for a 15 yr. period
Alpine	21	106	-2.	62	10
Balmorhea	21	110	-9.	64	12
Ft. Stockton	54	114	-7.	64	13
Marathon	15	106	-3.	60	-
O-Two Ranch	15	100	5.	64	-
Presidio	18	112	11.	68	17
Sanderson	9	105	2.	66	-

The U. S. Weather Bureau stations at Balmorhea and Ft. Stockton are situated at lower elevations and at some distances from the guayule areas, and, therefore, may not accurately reflect the temperatures to which guayule is exposed. However, several years of detailed data of these winter minima show that in all instances of unusual lows, they were accompanied by high north or northwest winds, and appear to be invasions of cold originating in storm areas to the northward. If this were always the case, the temperatures at the guayule areas were probably at least as cold as those recorded at the weather

stations. If the air were calm during these minima the guayule areas may have been warmer, but high wind appears to be the rule during periods of unusual winter cold.

DOMESTICATION

Serious thought was first given to the domestication of guayule when it became obvious that unlimited milling of the wild shrub would soon deplete the native stands. Between 1900 and 1910 several mills were established near the guayule areas of Mexico and one was put in operation at Marathon, Texas.

For the purpose of making a thorough study of guayule and its possibilities as a cultivated plant, Francis Ernest Lloyd, Professor of Plant Physiology at the Alabama Polytechnic Institute, had been commissioned to make the investigations which resulted in the publication of his excellent treatise, "Guayule, a Rubber-plant of the Chihuahuan Desert."

During 1911 and 1912, Dr. W. B. McCallum, in the employ of the Continental-Mexican Rubber Company, gathered seed from the wild shrub on the Cedros Ranch in the State of Zacatecas, Mexico. During 1913 and 1914, this seed was planted near Valley Center, San Diego County, California. From this original batch of seed and the subsequent progeny of plants, have evolved, through the processes of selection, our current cultivated varieties of guayule, principally strains 406 and 593. The experimental work was transferred to Continental, Arizona in 1914, and moved again from there to Salinas, California during 1923-25.

In making his original selections, Dr. McCallum was primarily interested in developing varieties which would produce a maximum yield of rubber hydrocarbon. Minimum temperatures of the Arizona and California stations were quite comparable to those of Cedros, Mexico and cold tolerance was not considered a factor of importance. Therefore, the lower climatic limitations of the current varieties were not fully known.

It may be observed here that the Soviets, working independently, developed several varieties of their own, two or three of which are reported to be exceptionally tolerant to cold -- work which is reviewed later in the report.

When the Emergency Rubber Project took over the holding of the Intercontinental Rubber Company early in 1942, the Project was commissioned to expand the planting of guayule into those areas in the United States where soils and climatic environments were suitable. It was recognized that this climatic limitation imposed by the shrub's intolerance to high rainfall and low temperatures might seriously limit the amount of suitable land that could be found. The best commercial strains in use by the Intercontinental Rubber Company were developed from stock originally collected in the most southern part of the native range, and little was known about their hardiness. One way of increasing the planting range was the development of more cold resistant varieties. With this in mind, plant breeding work was started early in the Project's history by the Bureau of Plant Industry,

Soils, and Agricultural Engineering, and seed stock was gathered from several parts of the wild range. Plant breeding in its very nature is time-consuming research, and under the urgency of the period test plantings were made of the existing varieties to find the geographic limitations of the then available planting stocks.

Essentially the plantings were of two types. The first were those made by the Project in areas in the four states of California, Arizona, New Mexico, and Texas where there was a likelihood that the plants might survive and produce, yet where the data on environmental tolerance was too meagre to give a definite answer without an actual test by the plant itself. The second grew out of interest in guayule by other agencies and individuals and resulted in plantings being made in several of the other states, many of which were generally considered out of the range of possible successful production. These latter ranged from plantings of a few individual plants to several hundred and their location and fate is given in the attached tabulation furnished through the courtesy of Dr. A. C. Hildreth of the Bureau of Plant Industry, Soils and Agricultural Engineering, who was in charge of the Research program of the Emergency Rubber Project.

In addition to these, the Bureau made plantings at Pullman, Washington: Albuquerque, New Mexico; and Woodward, Oklahoma in the spring of 1943. There were 5,000 plants used at each station. These were plants grown from wild seed gathered at various locations in the Big Bend and Mexico. All the plants were killed the first winter at Pullman and Albuquerque, and only 20 plants survived at Woodward. It may be significant that 19 of these 20 were from seed gathered near Sanderson, Texas on the colder northern margin of the native range. None of the 20, however, survived the following winter.

One of the privately planted plots deserves special notice. This was one made in the spring of 1942 by Mrs. R. L. Duke of Dalhart, Texas, with some seedling plants of variety 593 sent her by Dr. McCallum from Salinas. They were planted in a somewhat protected area of her garden, and of the 127 plants entering the first winter, 39 survived the coldest temperature on record at Dalhart when the minimum went to minus 17 degrees. The following winter all of these plants, including some volunteer seedlings, survived a minimum of zero degrees. Mrs. Duke stated that during the coldest periods of both years the plants were well covered with snow, which would greatly help the survival chances.

The Project-planted Indicator Plots were more permanent in nature; that is, they were established with the intention of being continued for a period of several years. There were 146 of these ranging from the northern end of the Sacramento Valley in California southward through southern Arizona, New Mexico and eastward into central and southern Texas. Since low temperatures are rarely experienced in the California and Arizona areas where the plots were established the observations herein reported were made only in Texas and New Mexico. Of the 146 plots, five were planted in New Mexico and 47 in Texas. Two of the Texas plots were lost by flood the first season and were not replanted. Twenty-six of these 50 were planted in the spring of 1942. The majority of the remaining 24 were planted one-half in the spring of 1943, and one-half in the fall of the same year.

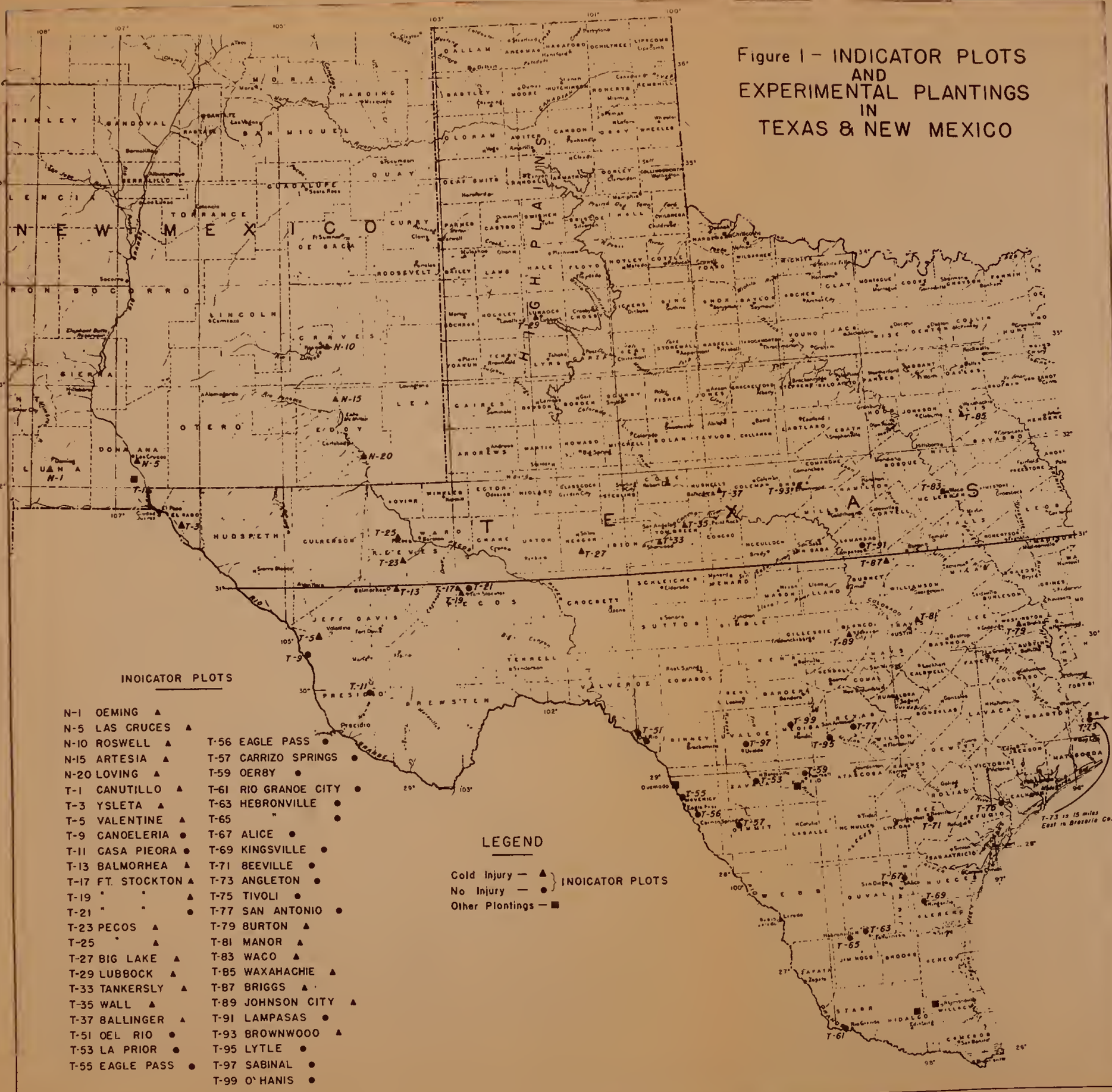


Figure 1 – INDICATOR PLOTS AND EXPERIMENTAL PLANTINGS IN TEXAS & NEW MEXICO
INOICATOR PLOTS
N-1 OEMING ▲
N-5 LAS CRUCES ▲
N-10 ROSWELL ▲
N-15 ARTESIA ▲
N-20 LOVING ▲
T-1 CANUTILLO ▲
T-3 YSLETA ▲
T-5 VALENTINE ▲
T-9 CANOELERIA ●
T-11 CASA PIEORA ●
T-13 BALMORHEA ▲
T-17 FT. STOCKTON ▲
T-19 " " ▲
T-21 " " ●
T-23 PECOS ▲
T-25 " ▲
T-27 BIG LAKE ▲
T-29 LUBBOCK ▲
T-33 TANKERSLY ▲
T-35 WALL ▲
T-37 BALLINGER ▲
T-51 OEL RIO ●
T-53 LA PRIOR ●
T-55 EAGLE PASS ●
T-56 EAGLE PASS ●
T-57 CARRIZO SPRINGS ●
T-59 OERBY ●
T-61 RIO GRANOE CITY ●
T-63 HEBRONVILLE ●
T-65 " ●
T-67 ALICE ●
T-69 KINGSVILLE ●
T-71 BEEVILLE ●
T-73 ANGLETON ●
T-75 TIVOLI ●
T-77 SAN ANTONIO ●
T-79 BURTON ▲
T-81 MANOR ▲
T-83 WACO ▲
T-85 WAXAHACHIE ▲
T-87 BRIGGS ▲
T-89 JOHNSON CITY ▲
T-91 LAMPASAS ●
T-93 BROWNWOOO ▲
T-95 LYTLE ●
T-97 SABINAL ●
T-99 O'HANIS ●
LEGEND
Cold Injury — ▲
No Injury — ●
} INOICATOR PLOTS
Other Plantings — ■
T-73 is 15 miles East to Brazoria Co.

OTHER LOCATIONS IN THE UNITED STATES WHERE SMALL PLANTINGS OF GUAYULE WERE MADE IN 1942 AND 1943*

Location	No. of Plants	Planted	Remarks
Raleigh, N.C. Exp. Station	25	5/42	Plants made fair growth. Five plants lost at Raleigh due to S. rolfsii. At Willard prolonged rainy spell resulted in some damage from weeds. None of the plants survived the winter. Early severe cold weather was followed by a warm spell which encouraged growth; then sudden severe cold temperatures in February, 10° to 14° F., killed those plants which had withstood earlier cold. No evidence of nematode infestation at Raleigh even though a very heavy infestation of this parasite is known to be in the soil in which this plot was planted.
Willard, N.C. Exp. Station	25	5/42	
Albuquerque, N.M. Soil Conservation Service		Spring 1942	Week of below zero temperatures killed entire planting.
Stillwater, Okla. A&M College		Spring 1942	Heavy rains prevailed during summer 1942. Plants made good growth. Growth stopped by cold weather in November. All plants entirely killed by cold weather in January and March of 1943.
Stillwater, Okla. A&M College		Spring 1943	Planted in greenhouse, because of lack of space, removed latter part of June and planted in field, where extreme heat and dry weather killed them all.
Chickasha, Okla. Soil Conservation Service		Spring 1942	Unusually heavy rains in growing season, Irrigated once, when planted. Cold winter weather, 4 below zero, killed them all.
Lincoln, Nebr. North Platte Scottsbluff, and Alliance.	200 to 300	Spring 1942	Small plantings, all killed following winter.

* See acknowledgement preceding page.

OTHER LOCATIONS IN THE UNITED STATES WHERE SMALL PLANTINGS OF GUAYULE WERE MADE IN 1942 AND 1943

Location	No. of Plants	Planted	Remarks
Fort Collins, Colo. Exp. Sta.	60	Spring 1942	47 plants established. These made fair growth. All killed by 1942 and 1943 winter temperatures.
Akron, Colo.	54	S/42	37 plants became established. All killed following winter.
Ft. Lewis, Colo	50	S/42	24 plants became established. All killed following winter.
Center, Colo.	30	S/42	20 plants became established. All plants died before cold weather.
Austin, Colo.	74	S/42	69 plants established. All killed the following winter.
Fruita, Colo.	44	S/42	29 plants established. All plants died before cold weather.
Rocky Ford, Colo.	50	S/42	30 plants established. All killed the following winter.
Lamar, Colo.	23	S/42	12 plants established. All killed the following winter.
Trinidad, Colo.	35	S/42	39 plants established. All died before cold weather.
La Junta, Colo.		S/42	Number of plants planted unknown. Plowed up - lack of care.
Hays, Kansas Kansas State College		S/43	Unknown number of plants. All killed during the following winter.
Manhattan, Kansas Kansas State College	100	S/43	Withstood early light frosts. Minimum temperature of around 20° F. during late November killed the branches back to the main stem. Low temperatures during December killed all plants, both top and roots. A few of the plants had been planted at Garden City in southwest Kansas and were all winter killed even under a 6-inch mulch of soybean straw, sorghum and sesame stalks.

OTHER LOCATIONS IN THE UNITED STATES WHERE SMALL PLANTINGS OF GUAYULE WERE MADE IN 1942 AND 1943

Location	No. of Plants	Planted	Remarks
Talent, Ore. Southern Ore. Br. Exp. Sta.	10	Spring 1942	Five plants established, grew to average height of 15" x 12" wide first season. All plants winter killed, minimum temperature 11° F.
Astoria, Ore. Astor Exp. Sta.	24	S/42	12 plants established, made good growth during summer. Two plants produced flower stalks but no seed. Plants did not survive winter 1942-43. Minimum temperature 11° F. Also there were eight other days with temperatures of 15° to 24° F. This was the coldest winter in 75 years
Moro, Ore. Sherman Bros. Exp. Sta.		S/42	Unknown number of plants, made fair growth during summer of 1942. January temperature 14° below zero killed all plants.
Union, Ore. Eastern Oregon Exp. Station	24	S/42	Especially cold spring temperatures after planting. Many plants died soon after they were planted. By fall there were only five plants alive, but these were growing nicely. Minimum temperature of 27° below zero in January, and none survived.
Klamath Falls, Ohio Klamath Exp. Area		S/42	Unknown number of plants. Made fair growth during summer. 4° F. below zero killed them.
Corvallis, Ore. Oregon Exp. Sta.	24 12	S/42 S/42	These were set on Willamette silty clay loam. None survived transplanting. These were set on Chehalis silty clay loam. There was a 100% establishment. All produced flowers and set some seed late in season. No plants survived the 1942-43 winter temperatures and high flood waters.
Prosser, Wash. Irrig. Br. Exp. Sta.	200	S/42	Good summer growth and establishment but did not survive winter.
Puyallup, Wash. Western Wash. Exp. Sta.	100	S/42	Did not survive the winter.
Pullman, Wash. Div. of Forrestry & Agromony State College of Wash.		S/42	Unknown number of plants. All killed by cold weather the following winter.

COLD INJURY OBSERVATIONS

During the period of observation, 1942-45, the 31st parallel of latitude appeared to form a boundary which remained quite constant in separating the cold injured plots from those which suffered little or no damage. Generally speaking, the farther the plots lay north of this boundary, the more severe the injury. Conversely, the farther south from the line the less the injury, if any. For discussion purposes the region lying north of the 31st parallel will be indentified as the "critical area." It is interesting to note that latitude 31 degrees marks the northern boundary of the range of the native guayule.

All of the 1942 plantings in the critical area showed cold injury in greater or less degree in one or more of the three years of observation. All plots planted in this area in the spring of 1943 were severely damaged the winter following, and the fall plantings on these plots were entirely killed out the same winter.

Early in the investigation it became evident that the degree of injury was seldom in direct ratio to the degrees of cold; rather, injury appeared influenced by variations in the amount of soil moisture. This soil moisture correlation, however, exhibited unexplained irregularities, and the amount of injury might vary greatly between plots which apparently had about the same amount of available moisture and comparable exposure to low temperatures. Therefore, other factors that might enter into injury were examined such as soil textures, air drainage and wind, the pattern of low temperatures, and the degree of plant dormancy at the time low temperatures prevailed.

In the spring of 1943 and again in 1944 any plot which experienced cold injury was investigated in detail. The plants were examined, given a rating for degree of injury, and recorded on a plot map with appropriate symbol.

Data on which to base the interpretations were obtained from several sources. Detailed soil studies had been made of all plots. (10). The data from these on textures and profile characteristics, when used in conjunction with test borings made at the time the plots were examined for cold injury, provided comparative values on the amount of available moisture present. If not available at the plot, weather data was obtained from the Weather Bureau station nearest to the plot concerned. This was not all that could be desired, but in most cases it was possible to set up recording instruments on the plots for an interval of time from which a reasonably accurate adjustment could be worked out. The monthly reports on irrigation and cultivation were also consulted regularly, and topography, air drainage, windbreak, and so forth were noted and recorded.

In assessing the degree of injury the following system has been used:

1. No injury - or too minute to be observed readily
2. Slight - injury of terminals to 2-1/2 inches
3. Moderate - injury to as much as 2/3 of plant volume
4. Severe - all aerial portions of plant killed
5. Complete - beyond recovery

It is obvious that this classification is arbitrary and does not cover all types of injury, but it was found that a more detailed breakdown involved much more time and served the purpose of this study no better. Since "1" represents no injury and "5" represents plants totally killed, there were only three classifications of degree to make, "2," "3" and "4," and, while there were naturally many borderline cases, the class interval was sufficiently distinct to produce a definite pattern. No account has been taken of injury to leaves. Although uninjured foliage, which remains on the plant through the winter months, continues to perform physiological functions for three or four months of the following growing season, and although loss of leaves, either in whole or in part unquestionably affect the plant, this class of injury was omitted because of the difficulty of setting up any categories of intensities. Observations of defoliated plants during the weeks of early spring growth revealed that they put out more foliage than undefoliated plants, and apparently there was much compensation. Comparative measurements made at the end of two weeks' growth disclosed no significant difference in size and vigor between plants with injured and non-injured foliage.

Following is a discussion of the individual plots in the "cold belt" and their reaction to low temperatures and moisture factors insofar as these could be determined by the type of investigation made.

INDICATOR PLOTS - 1942

Deming Indicator Plot, N-1, Deming, New Mexico

The Deming plot was located 12 miles southwest from Deming on the L. L. Kinney farm. The plot was irrigated from a deep well with a good quality of water.

The soil is Karro clay, sterile and rather impermeable. The Karro soils lie at the outer edges of the Mimbres Valley, are not extensive, and are seldom used for crop lands because of their sterility. Surface drainage on the plot was good.

It was planted April 6 and 7, 1942, with equal amounts of varieties 406 and 593, spaced 33" x 18". In spite of irregular irrigation and poor distribution of the water the survival at the end of the first season was reported to be 62 percent.

In early January of 1943 the plants were inspected and found free from disease, of good color, but only about one-half the size of plants at the other New Mexico plots. During January and February the planting was almost destroyed by rabbits, and most of the plants were eaten to the surface of the ground. Less than 25 percent survived the attack. The remaining plants showed no injury from cold despite a minimum of 15 degrees F., which they had just passed through.

The injury the second winter was slight to moderate. No temperatures are available from the Weather Bureau for the winter of 1943-44, but a locally kept record shows a minimum of 8 degrees during January, which minimum has been accepted though its accuracy may be off a slight amount either way.

The plants had made a good growth the second season and had remained free of disease, and when visited in November were quite dormant. This dormancy and freedom from disease were apparently the principal factors contributing to the small amount of injury sustained during the critical period.

Injured plants were evenly divided between varieties 406 and 593.

Degrees of Injury - Deming Plot - Winter of 1943-44

Degrees of Injury in Percent					No. live plants	No. of Orig. Plants	Percent Remaining 1944
1	2	3	4	5			
6.2	75.5	18.3	0,0	0.0	1363	9600	14.2

Las Cruces Indicator Plots, N-5, State College, New Mexico

The Las Cruces plots were located about four miles south and a little east of Las Cruces, New Mexico on the grounds of the U. S. Cotton Field Station. These plantings were made about 100 yards apart, the south one designated as D-4 and the north as B-5. They were located on an outwash plain of the Organ Mountains on a bench at about 35 feet above the Rio Grande flood plain in the Mesilla Valley. The original slope had a gradient of about 6 percent, but both plots had been leveled several years previously to form plane, level terraces.

The soil is described as Anthony sandy loam. Locally, the Anthony series was formed as outwash plains and alluvial fans which are usually underlain by gravel beds that may range from a few inches to several feet below the surface. The soil on the plots is light grayish brown in color and calcareous. It ranges in texture from a loam to a sandy loam, and in some places contains coarse gravel. Near the southwest corner of D-4 occurs a surface exposure of almost pure gravel. See figure 4. Leveling altered the original surface soil and it is atypical in many places. Since, however, the whole Anthony series is variable in texture and in depth to underlying gravel and since the leveling was done several years before the guayule was planted, it would appear that for practical purposes the changes brought about by leveling can be disregarded. The soils of the plot sites are friable and very permeable. In some places internal drainage is excessive and a wide range of available soil moistures are found.

The climate of the region is characterized by mild winters and hot summers, with rainfall much below the requirements for agricultural crops. Based on a forty year record the average temperature for July is 80 degrees F., and for January 41 degrees. The maximum recorded is 106 degrees and the minimum minus 8 degrees F. Temperatures below 20 degrees are not persistent and those below 15 degrees rare. Below freezing temperatures seldom extend for more than a few hours. The average precipitation at State College is 8.7 inches. Much of this occurs in showers too light to be effective. Cultivated crops depend on irrigation. The growing season is 208 days. Elevation is 3909 feet above sea level.

Fig. 2a Sub-plot B5 of Las Cruces guayule indicator plot, June 15, 1944. Cold injury visible but recovery under way.

Fig. 2b Sub-plot D4 of Las Cruces guayule indicator plot, June 15, 1944. Less injury than B5. Las Cruces, N. Mex.

The water for irrigation at the Station originates from diversion canals from the Rio Grande and is lifted to the terrace by pumps. The "flood" method of irrigation was used for the guayule plots. From 3-1/2 to 5 inches of water was applied at each irrigation, each application requiring about 45 minutes.

The plots were planted March 26, 1942. The rows of both plots ran from east to west, spaced 36" x 30" and planted check row. A few days after planting four areas were selected in the south plot (D-4) for interplanting to provide sub-plots with 36" x 15" spacing. See figure 4. The north plot was 138 x 165 feet in size and planted to 23 rows each of varieties 406 and 593. The south plot was 87 x 243 feet and planted to 14 rows of variety 406 and 15 of 593.

There was no injury to the plants of either plot during the winter of 1942-43 when the season's minimum of 13 degrees F. Was recorded on January 20. The plants were quite dormant and the soil rather dry throughout the winter months.

In the spring of 1943, plot B-5 was divided into six sub-plots by throwing up permanent irrigation levees or borders for a water application experiment by Artschwager (1) to determine the influence of varying soil moistures on the anatomy and physiological behavior of guayule. During the winter of 1943-44 both plots suffered moderate to severe injury. The lowest temperature recorded for the winter was 9 degrees above zero on January 10, 1944. Other minima were: 13 degrees on November 9, 1943, and 16 degrees on March 29, 1944.

The pattern of injury on the two plots was markedly different. See figures 3 and 4. On plot B-5 the injury pattern was obviously influenced by the location and direction of the irrigation levees separating the sub-plots. Tests for amount of moisture in the soil confirmed this by showing noticeably higher moisture in those areas which sustained the greatest amount of injury. The number of irrigations cannot be used as a basis for comparisons since the water was not metered and the time element was too crude a control to give much idea of what each plot actually received. Water spread across the plots in both a southerly and westerly direction and became impounded against the levees. Although sub-plots IV and V received the same number of irrigations the percentage of dead plants in V was higher due to the overflow into V from the impounded water when sub-plot I was irrigated and, also, because there was considerable sub-irrigation in the lowest corner of the plot. The influence of textures and water-holding capacities in the subplot were evidently submerged in the greater influence of excessive irrigation. Had the texture factor been operative the injury pattern would have, in one or more places, cut across the levees. This it did not do.

On the other had in sub-plot D-4 textures and water-holding capacities appeared to be the controlling factor drawing the pattern of cold injury. All concentrations of severe injury proved to be on the finest textured soils with the highest soil moisture. Also, some of these areas while only slightly depressed compared to the surrounding level, were enough so that several more inches of water could have accumulated in the profile.

In addition to the irregular areas of injury within the plot proper, there were two or three outside rows on the northern side which sustained a heavy loss. Here, too, the soil texture was much finer and moisture content greater than in the less injured areas. This unnatural shaped area proved to be the result of a back fill being made to raise the level of the ground at the time the terrace field was established.

The west end of the plot had the least injury. As outlined in figure 4, part of this area consisted of an exposed gravel surface, with the gravel dipping below the surface in a northwestward direction across the plot. In this area the plants were much smaller and because of more restricted moisture conditions had entered the winter in a semi-dormant condition as contrasted to the rest of the plot.

In both subplots injury pattern fell apparently more or less along the lines of the soil moisture patterns. In D-4 these were "natural," that is, differences in texture and water-holding capacity influenced the pattern. In B-5, on the other hand the effect of textures and holding capacities seemed largely submerged by forcing concentrations of water by artificial levees with a consequent injury pattern not so much associated with texture as with the physical amount of water present.

The temperature factor was the same intensity on both subplots, and on both there was considerable loss and injury which correlated with the amount of moisture in the soil. As will be shown later, however, coincidental soil moisture and temperature of similar magnitudes need not necessarily cause similar injury.

As will be seen in other plot records, guayule can go through low winter temperatures and under high soil moisture conditions with very little injury if the shrub is well advanced in dormancy before the advent of the critical cold period.

Whenever soil and temperature are favorable guayule will grow and bloom. In the Edinburg area of Texas where growing conditions are favorable nearly all the year guayule may be found in luxuriant growth and flower any month in the year. This habit makes the plant susceptible to the hazards of rapid changes in the weather. This appears to be what happened in the Las Cruces plots in 1943-44.

Both plots had received a complete irrigation on September 16, and all of B-5 was watered again in October. Growing temperatures were favorable during October with a mean day maximum of 77 degrees F. and a mean minimum of 40 degrees F. The first week in November continued to be favorable for guayule growth with day-time temperatures ranging from 70 degrees to 80 degrees F., and with night temperatures not sufficiently cool for a long enough period to materially check plant growth. When on November 8th and 9th temperatures of 15 and 13 degrees F., respectively, occurred the plants were not conditioned to meet it. These two minima fell in a period of cold nights during which the average minimum was 19.7 degrees F., and the average of day maximum had fallen ten degrees below the mean of the previous week.

Figure 3

DIAGRAMMATIC SKETCH OF COLD INJURY - WINTER 1943-44 ON SUB-PLOT B-5 OF LAS CRUCES GUAYULE INDICATOR PLOT

PLANT ABSENT | NO INJURY | ALL TERMINALS INJURED TO 3" | ONE THIRD OF BRANCHES KILLED
PLANT KILLED TO CROWN OR GROUND | TOTALLY KILLED - NO RECOVERY
IRRIGATION BORDERS SCALE 0 3 9 18 30 FEET

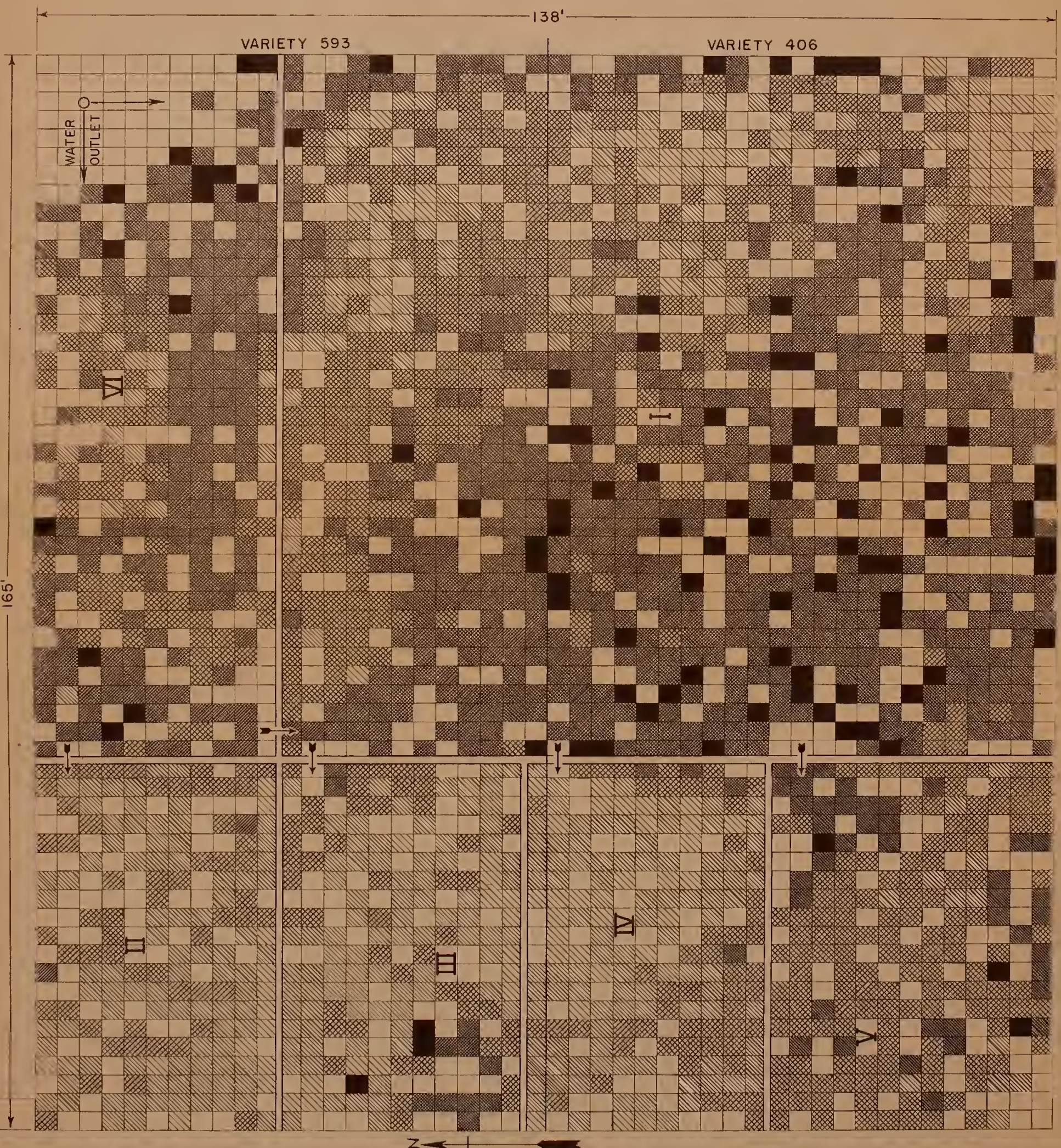
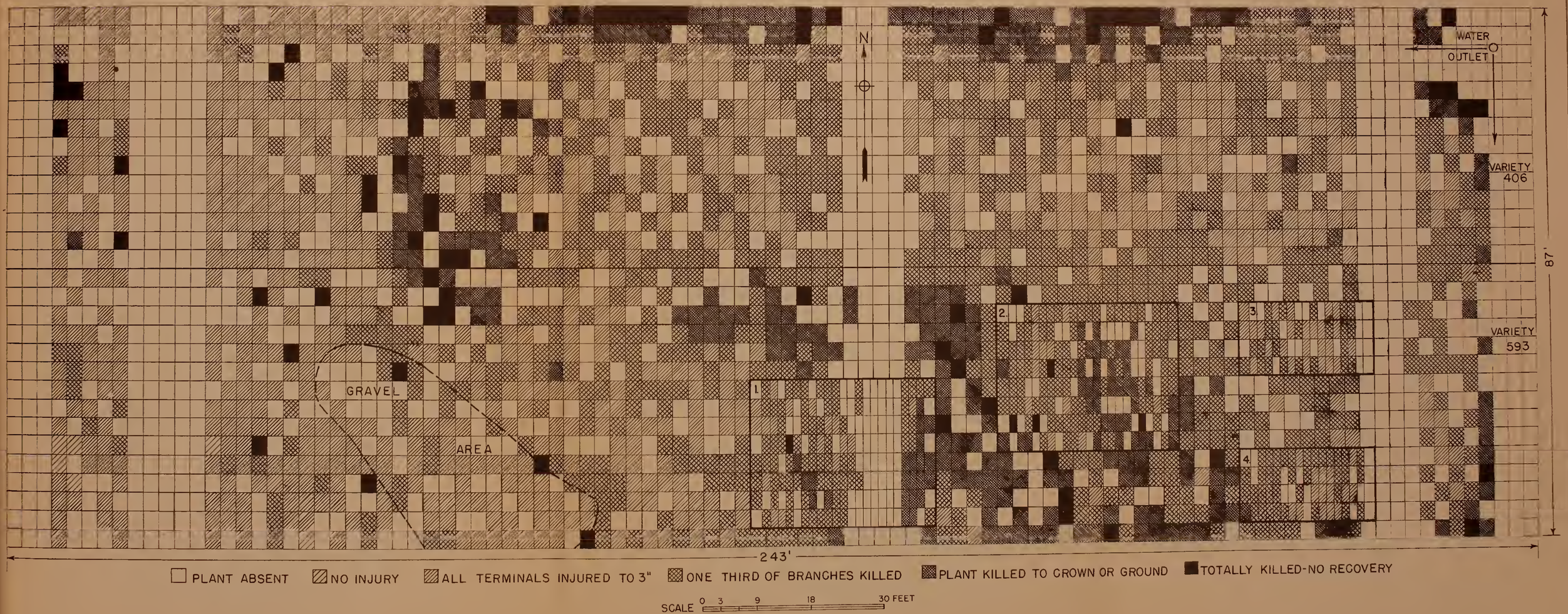


Figure 4

DIAGRAMMATIC SKETCH OF COLD INJURY- WINTER 1943-44 ON SUB-PLOT D-4 OF LAS CRUCES GUAYULE INDICATOR PLOT



It would appear that very little, if any, injury occurred after this cold period in early November. After the plants received the cold shock in November, the temperatures remained low more or less continously until February. These temperatures were much too cold for plant growth, and cold enough for a long enough time to have produced a degree of dormancy. It is, therefore, unlikely that the minimum of 9 degrees F. in January caused any further damage.

Interplanting was done on two areas in sub-plot D-4, increasing the number of plants two-fold per unit area. It might be expected that those plantings of greater density would have utilized more of the soil moisture and shown some reduction in the amount of cold injury. If any difference existed it was not significant.

Differences in cold tolerance between varieties 406 and 593 were not significant as may be readily noted in figures 3 and 4.

Roswell Indicator Plot, N-10, Roswell, New Mexico

The guayule indicator plot, N-10, was located about five miles southeast of Roswell, New Mexico on the farm of Howard Babcock, Jr. The plot site lies on a broad, gently sloping outwash alluvial plain to the west of the Pecos. The soil has been classified as Reeves silt loam, is quite friable when dry, has good permeability with a high water holding capacity. It is deep, calcarious, rich in organic matter and produces excellent crops such as cotton, corn, and alfalfa.

The average annual rainfall is 13 inches, and field crops must be irrigated. Deep wells supply the water. The mean temperature for Roswell is about the same as at State College, with about the same growing season (207 days) but extremes are wider, with a maximum of 110 degrees F. and a minimum of minus 29 degrees F. The cold season is subject to warm spells during which growing temperatures may prevail for several days which makes the area especially hazardous to guayule. Cold, high winds are frequent during winter months sweeping down the Pecos Valley, or they may come from the mountains to the west. These, when they occur, cause rapid changes in temperature; in the matter of a few hours growing temperatures may be replaced by several degrees of freezing. The altitude is 3,500 feet.

The plot was an acre in size and planted on April 1, 1942. The plants made an exceptional growth and the fall survival was 66 percent. Late in December a flock of sheep broke into the plot and ate most of the plants down to the main stems leaving only stubs about three or four inches above ground.

Only about 275, or 3.4 percent of the plants survived the winter of 1942-43. The soil was quite moist in November and the plants were not dormant. Minima of 10, 7 and 10 degrees F. were recorded at the nearest U. S. Weather Bureau Station for January 18, 19 and 20, respectively. Thermometer readings at the plot were two degrees lower than those recorded at the Bureau Station, or 8, 5 and 8 degrees F. It appears that much of the injury occurred during this period. The 48 days in December and January prior to these minima had 39 days with maxima of 50 degrees F. or higher,

and of those 17 ranged from 65 degrees F. to 73 degrees F. The low temperatures appear to have been too infrequent and of too short duration to have caused complete dormancy.

During the second growing season the surviving plants made a good growth, as also did numerous volunteer seedlings. The soil was very wet when visited in November 1943. December was a wet month, two inches of rain falling on the ninth. On the night of December 27-28 the temperature fell to 8 degrees F. at the U. S. Weather Station. On January 8 the minimum of 8 degrees F. was again recorded at the U. S. Weather Station. These readings appear to have agreed with temperatures taken at the plot.

No plants survived the winter of 1943-44. The high degree of soil moisture of the plot, the fact that the plants were not entirely dormant in November, and the sudden drop in temperature are probably the causes of the total loss of plants.

Degree of Injury - Roswell Indicator Plot - Winter of 1943-44

Degree of Injury					No. Live Plants	No. Plants Planted	Percent Remaining 1944
1	2	3	4	5			
				100.0	0.0	8,000	0.0

Artesia Indicator Plot, N-15, Artesia, New Mexico

This plot was located about four miles southeast of Artesia on the farm of J. W. Berry. The site lies in the same general plain and in about the same relation to the Pecos River as the Roswell plot. The soil also belongs to the Reeves series, but is more variable and contains spots of caliche. Internal drainage is sluggish in places and there are areas which tend to have perched water tables because of the presence of clay layers.

Artesia is somewhat warmer than Roswell, but extremes of temperature are greater, the official record giving a range from an absolute maximum of 116 to a minimum of minus 35 degrees F. Sub-zero temperatures are infrequent, but quite unseasonably warm periods occur during the cold season followed by rapid transition to sub-freezing cold. The elevation is 3,350 feet and the average precipitation is about 12 inches. The land is irrigated from deep wells.

The plot, about 1-1/2 acres, was planted March 30, 1942 with a spacing of 30" x 38". There were an equal number of rows of varieties 406 and 593. The plants made an excellent growth the first season, but disease appeared in the fall which badly injured or killed some of the plants.

Investigations in the spring of 1943 revealed slight to moderate injury by cold. The surface soil was still quite moist in October, sub-soil moisture was high and the plants continued some growth late in the fall season. The pattern of injury lay through the central and western portions of the plot with concentrations of injury, both from cold and disease, in small areas which had inadequate surface drainage and along certain rows. Over the east

third of the plot, injury was quite uniform in distribution but with a lower percent of severe and complete injuries than occurred on the west two-thirds. The pattern of injury which fell along certain rows was apparently brought about because these rows had been used to conduct water to a large field which lay below the guayule planting. Tests disclosed that the sub-soil moisture was definitely higher under these rows than in the remainder of the plot.

Degree of Injury - Artesia Indicator Plot - Winter of 1942-43

Degree of Injury in Percent					
Uninjured				Dead	Killed by Disease
1	2	3	4	5	
25.5	43.8	14.3	8.3	3.4	3.7

Weather Bureau minima for the winter were 10 degrees F. on December 28, and 8 degrees F. on January 18, 1943. Temperatures at the plot during the winter were two or three degrees lower as evidenced from a recording thermograph located on the plot. It could not be determined on which date the injury occurred, and while it is possible both lows contributed, no cold injury was observed when the plot was visited on January 11. However, injury unless severe may be difficult to detect in the winter time.

Before irrigations were started in 1943, the plot was equally divided into two sub-plots for a dry-land and irrigation experiment. The plot was divided across the rows from east to west. The dry sub-plot received no further irrigation. In order to avoid running water through the plot to the cultivated field to the south, a lateral was built around the sub-plots.

Both the dry and the irrigated sub-plots were severely injured during the second winter, 1943-44. While 93.2 percent of the plants in the irrigated portion were totally killed, only a 45.9 percent loss occurred on the dry-land sub-plot. The dry plot had the better surface and internal drainage which could be expected to accentuate the difference. Of the 126 surviving plants in the irrigated sub-plot, 110 were concentrated along the east two or three rows while the other 16 plants, all class 4 injury, were quite evenly distributed over the balance of the plot. These east rows were that part of the plot which had not been used for conducting water to the cultivated field below the guayule during the season of 1942.

The lowest temperature for the winter was 8 degrees F. on January 7. Minima of 14 degrees F. on November 7, and 15 degrees F. on December 27, and 12 degrees F. on March 28 also occurred.

A comparison of the injury that occurred in the two winters does not permit an interpretation made on the difference in available soil moisture or degree of cold. The dry sub-plot in the winter of 1943-44 obviously had a drier soil environment and was subjected to no lower temperatures (actually) about two or three degrees less) than the plot had experienced the previous winter. Yet the sub-plot had a 45.9 percent kill the second winter as against a 3.4 percent for the entire plot in the winter of 1942-43. While this 3.4 percent represented the loss on the entire plot, it can be fairly

used for comparison since the east-west division made in the spring of 1943 also made about an equal distribution between the two sub-plots of the number of killed plants the first winter.

The explanation seems to lie in the temperature pattern. The first winter, 1942-43, began with a more gradual approach to temperatures of freezing and below. This downward trend began early in November and by successive slight increments of cold finally reached a minimum of 17 degrees on November 22. Minimum temperatures below freezing, which kept the plants in apparent dormancy, prevailed throughout the remainder of the winter. Therefore, the plants remained in a hardened condition and were apparently only slightly injured by the 10-degree low on December 18 and or the 8-degree low on January 18.

On the other hand, no gradual transition to winter cold levels took place in the late fall and early winter of 1943-44. The month of October and the first week in November were characterized by high temperatures which kept the plants actively growing. Without any tempering cold nights, the temperature suddenly dropped to 14 degrees above on November 7. Considerable injury occurred, although no attempt was made to evaluate the percentage at that time. Generally, minima temperatures remained low through the rest of November, December, January, and the first half of February. Then six weeks of favorable growing temperatures followed until March 28 when a sharp drop to a minimum of 12 degrees occurred.

It would appear evident, therefore, that the "physiological status" of the plant as brought about by certain patterns of conditioning temperatures can give the plant a high resistance to cold regardless of the amount of available moisture that is in the soil. On the other hand it would appear that soil moisture, or at least the amount of soil moisture can also be a major contributing factor as shown by the difference in mortality between the dry and irrigated sub-plots exposed to the same temperatures and temperature pattern. It would appear that either a sufficient drouth stress preceding cold temperatures, or a temperature pattern of progressive and slightly lowering levels of cold which carry the plant gradually into a dormant condition, even in the presence of abundant soil moisture, gives guayule a marked advantage in its resistance to cold.

Degree of Injury - Artesia Indicator Plot - Winter of 1943-44

	Degree of Injury in Percent					No. Live Plants	No. Plants Planted	Percent Remaining 1944
	1	2	3	4	5			
Dry Sub-plot	0.0	1.1	12.4	40.5	45.9	1,158	3,851	30.1
Irr. Sub-plot	0.0	0.0	1.9	4.8	93.2	126	3,851	3.3

Loving Indicator Plot, N-20, Loving, New Mexico

The Loving Indicator plot was located about 4-1/2 miles south-east of Loving, New Mexico on the farm of C. Y. Beeman. The soil has been mapped as belonging to the Reeves series, with Reeves loam, deep phase, occurring on the west two-

thirds of the plot and with gravelly loam, shallow phase, on the east end. The surface was permeable, internal drainage fair with high water-holding capacity and with surface drainage good to excessive. The plot was never leveled for irrigation and, therefore, the water distribution was always uneven and spotted and resulted in plant growth and survival that was correspondingly lacking in uniformity. Irrigation water was furnished through canals from the Pecos River. The water was high in salt content.

The plot was planted March 30, 1943. Establishment was very poor due to infrequent irrigation, inadequate distribution of water, and improper cultivation during the first season, During the latter part of the 1942 growing season, many plants were lost by crown rot and root rot. In the fall of 1942, a survival of 24 percent was reported. The plants were small, in size about one-half that of the plants at Artesia.

The plot was inspected in January 1943, and the plants appeared dormant, healthy and of good color. Inspections in March and May of 1943 revealed no injury from the cold of the past winter during which a low of 12 degrees F. had occurred.

The plot received much better care during the growing season of 1943. The shrub grew more rapidly and entered the fall in good vigor. A very heavy irrigation was applied on September 5, 1943, and was followed by thorough cultivations in mid-September and early October. The plants were not fully dormant when they entered the winter. On January 6, 1944 slight frost injury was observed.

Degree of Injury - Loving Indicator Plot - Winter of 1943-44

Degree of Injury in Percent					No. Live Plants	No. Plants Planted	Percent Remaining 1944
1	2	3	4	5			
27.4	61.9	10.7	0.0	0.0	749	6,080	12.32

Canutillo Indicator Plot, T-1, Canutillo, Texas

The Canutillo Indicator plot, also known as the Ord Gary indicator plot, was located 2-1/4 miles southwest of Canutillo, Texas in the Mesilla Valley.

The nearest official weather station is 7 miles east of El Paso, Texas, and 17 miles distant from the plot, but temperatures and climate, generally, more nearly approximate those recorded at State College, New Mexico, 25 miles up the valley. The plot elevation was about 3,800 feet. Summer maxima are three to four degrees warmer than State College and winter minima are usually about one to two degrees warmer.

The plot was about one acre in size, and the soils were fairly typical of those of the Mesilla Valley which are extensively planted to cotton, some corn, alfalfa, and vegetable crops. Irrigation water is conducted by canals from Rio Grande, and is quite high in soluble salts.

Detailed soil surveys were made of the plot and the soils classified as

belonging to the Gila and Pima series, with silty clay loams and sandy clay loams predominating. The soils are quite permeable but water-holding capacity is high and surface drainage poor in several places.

The plot was planted March 21, 1942 with 22 rows each of varieties 406 and 593, spaced 40" x 30". The original survival and early growth were excellent, and by July 1 the plot did well to be the finest planting in the Texas-New Mexico district. During July root rot began to appear and by October about one-third of the stand had been destroyed by disease. Undiseased plants were of good color in January 1943, and ranked about the largest in size for the district. A low temperature of 14 degrees F. for the winter of 1942-43 caused no injury to the plants.

Disease continued to infest the plot during the growing season of 1943. The plants received four irrigations during the season, the last one on September 15. In August, irrigating water from an adjacent field escaped and heavily flooded part of the plot. This flooding aided the spread of disease. As of December 13, 1943, 44.7 percent of the plants were killed by disease. When cold weather began, the plants still showed considerable growth activity.

On May 8, 1944, when the plot was inspected again, it showed serious injury from cold. The distribution of damage was very irregular. The plants that had died from disease the previous season were still standing in the field and were concentrated in areas that appeared low. It was near these areas that the greatest cold injury occurred, and there either was some correlation of cold injury and disease or similar soil conditions had been contributing factors to both injuries. Wet soils are more favorable for the spread of root rot and crown rot than dry soils. While the diseased plants may well succumb to cold more readily than healthy plants, plants associated with the highest soil moisture are usually the most suspectible also, and it can not be definitely stated which, if either, was the most important on this plot.

The minimum temperature for the winter of 1943-44 was 10 degrees F. on the night of January 9-10. Some injury may have occurred during the period of this minimum, but since the weather pattern at this location follows quite closely that of State College it would appear justified to conclude that greater injury occurred during November 8 and 9 when minima there fell to 15 and 13 degrees F., respectively. Since this cold period was accompanied by northerly winds, minima were probably not more than one or two degrees higher than at State College.

Examination of soil moisture failed to give a very satisfactory correlation between moisture and injury at this plot. Injury fell in rather small patterns with relatively large percentages of dead plants, and differences in soil moisture were too slight to appear significant.

On the two areas of fine sandy loam with a permeable profile throughout, the least number of plants and lowest degree of injury occurred. Disease was also least prevalent on these areas.

Degree of Injury - Canutillo Indicator Plot - Winter of 1943-44

Degree of Injury in Percent					No. Live Plants	No. Plants Planted	Percent Remaining 1944
1	2	3	4	5			
0.0	24.4	26.0	44.0	5.6	929	4,928	18.83

Ysleta Indicator Plot, T-3, Ysleta, Texas

The Ysleta Indicator plot was located about 3 miles northeast of Ysleta, Texas, and about 14 miles southeast of El Paso, on the Texas-El Paso Valley Agricultural Experiment Station. The area is known locally as the El Paso Valley, and lies in the valley floor of the Rio Grande.

Similar in many respects to the Mesilla Valley, the weather patterns are significantly different due to the impingement of the mountains against the Rio Grande in the vicinity of El Paso, a physical characteristic which modifies considerably the winter "northers." A reflection of this modification is found in the comparison of the growing seasons -- 238 days at El Paso as against 208 at State College about 50 air miles distant.

Field crops, such as cotton, forage crops and vegetables, depend on irrigation water diverted from the Rio Grande by canals. The salt content of the water is high at times, and caution must be used to prevent salt concentrations in the soil.

The plot, about 3/4 of an acre, was planted March 22, 1942. The surface soils ranged from clay loams to very fine sand. The original survival was poor due to improper leveling of the land prior to planting which resulted in surface concentrations of water and the total loss of plants in the depressional areas.

At the end of the first growing season the shrub on this plot was the most variable in size of any in the Texas-New Mexico region, some of the plants had made excellent growth while others were about one-fourth the size of the best. Many of the smallest plants were adjacent to the barren areas where the original survival loss had taken place. Moving outward from the bare areas the plants increased in size in a definite concentric manner.

In other parts of the plot sand and gravel lay only 12-18 inches below the surface, and here, too, the plants were very small because of inadequate moisture.

The lowest temperature for the plot during the winter of 1942-43 was 14 degrees F. No injury was evident when the plot was inspected for cold damage on March 23, 1943.

A good growth was made during the summer of 1943, but disease continued to affect the plants and by fall 120 had died. The plot had received 6 irrigations during the season, the last on November 17. Shrub went into the winter in a succulent condition. Cold injury for the winter of 1943-44 was quite severe despite the fact that the absolute minimum was only 11 degrees F., occurring January 9.

The degrees of injury were not evenly distributed over the plot, but occurred in patches of "3s" or "4s." Around the barren spots the degrees of injury occurred in concentric rings corresponding to the growth circles mentioned earlier, with the "4" and "5" injuries on the inside, the "3s" next, and with "3s" and "2s" mixed in the outer perimeter. This type of injury and arrangement of size was unique among the plots studied, and one surmise was that there might be some correlation with alkali. However, tests for salts did not get differences of great enough magnitude or pattern to appear significant.

There was, however, a definite correlation with the concentric pattern with clay lenses which lay below these areas at various depths. These lenses caused the formation of temporary water tables, and the gradation in size of shrub that occurred appeared to be caused by a progressive dimunition in the amount of aerated soil that was available to the guayule roots as they approached the centre of the area.

The soils, as classified, belong to two series, the Gila and the Vinton, with the principle difference being that Gila series are those with sands and coarse materials occurring at 60 inches or lower, and the Vinton with this type of previous material occurring at shallower depths. It was on the Vinton soil with sand and gravel occurring at from 12 to 18 inches and excessive internal drainage that the smallest plants occurred. For the same reason, these plants were in a hardened condition when low temperatures occurred and consequently suffered least from cold injury.

The spotted occurrence of cold injury at the Ysleta plot indicates that plant injury was greater in proportion to the degree of available soil moisture.

Degree of Injury - Ysleta Indicator Plot - Winter of 1943-44

Degree of Injury in Percent					No. Live Plants	No. Plants Planted	Percent Remaining 1944
1	2	3	4	5			
0.0	31.2	37.9	22.3	8.5	2034	4500	45.2

Valentine Indicator Plot, T-5, Valentine, Texas

The Valentine Indicator plot was located on the E. C. Miller ranch, about 10 miles southwest of Valentine, Texas at the east base of the Tierra Vieja Mountain Range. Valentine is in the Big Bend of Texas, and this plot is about 75 miles northwest of the O-Two Ranch, the center of the native guayule stand in the United States.

The soils are Verhalen silt loam and Verhalen clay loam. They have rather slow intake of water, and slow internal drainage with high moisture holding capacity. Surface drainage was fair. Irrigation water was supplied from a spring.

The planting was made April 1, 1942. The spacing was 30" x 20". The original survival was low because of faulty care and inadequate irrigation.

Most of the growth during the first season followed heavy rains in August and September. The fall survival, 1942, was 37 percent.

When the adverse conditions under which this plot was established are considered, the stand and growth made was not discouraging. Actually the plot received very little irrigation water the first season and received only two during the summer of 1943. Tilth was always poor. The plot never suffered from disease. The plants were unusually sturdy in appearance, with thick tree-like branches, Shrub from this plot was sent to California and showed excellent milling qualities with high rubber content.

No injury occurred during the winter of 1942-43, but during the winter of 1943-44 a few twigs were killed back about 4 inches. This injury is not as great as the statistics indicate, since only a few branches on individual plants were injured, and by July of 1944 it was difficult to detect any damage.

There are no official temperature records available for this area, but Mr. Miller, owner of the land on which the plot was located, reported it cold enough to kill the fruit crop, an infrequent occurrence.

Degrees of Injury - Valentine Indicator Plot - Winter of 1943-44

Degree of Injury in Percent					No. Live Plants	No. Plants Planted	Percent Remaining 1944
1	2	3	4	5			
26.7	44.8	28.5	0.0	0.0	1342	4900	27.4

Balmorhea Indicator Plot, T-13, Balmorhea, Texas

The Balmorhea Indicator plot is located 4-1/2 miles east of Balmorhea, Texas, on grounds of the Texas Agricultural Experiment Station. The plot site was about 15 miles west of natural stands of guayule that grow along the escarpments just south of U. S. Highway No. 290

The soils are alluvial in origin, part of the wide flood plain of Toyah Creek, and are described as Toyah silt loam and Toyah silty clay loam, with several phase variations including some alkali. They are quite friable, with medium infiltration and high water-holding capacity. Internal drainage is variable and imperfect in places. Surface drainage was fair. Irrigation water originates at "Big Springs" near Toyahville and the water has a rather high saline content.

The plot was planted March 27, 1942 and consisted of 4 rows each of varieties No. 406 and No. 593, and the rows were about 1120 feet long, with spacing of 30" x 40". The survival was 77 percent in July. This would have been even better had the lower end of the plot received sufficient amount of water on the first irrigations.

In late July 1942 the plot became infested with carrot beetle, and later, crown and root rot. By December the stand had been reduced to about 60 percent. The remaining plants ranked high in size as compared with other

plots in Texas, with an average measurement of 11" high and 16" broad. During the winter of 1942-43 the planting withstood a low temperature of 10 degrees F., on January 19, 1943 with injury. The plot had received five irrigations for the year.

During the growing season of 1943 the plants grew well, but there were some further losses from carrot beetles and various rot diseases. The latest of the season's five irrigations was on September 6, 1943.

A temperature of 17 degrees F., on January 8, 1944 caused some slight cold injury. Although the count showed that 32.5 percent of the plants had been injured, the injury was so slight that it hardly deserved the rating of "2" damage. Only a few of the terminals of the plants so designated were injured, and none of these to exceed one-fourth to one-half inch, whereas the designation of "2" allows an injury up to 2-1/2 inches. The injury was evenly distributed over the plot, and when inspected on May 5, 1944 it was difficult to determine injury except by careful examination of each plant.

Degrees of Injury - Balmorhea Indicator Plot - Winter of 1943-44

Degrees of Injury in Percent					No. Live Plants	No. Plants Planted	Percent Remaining 1944
1	2	3	4	5			
67.5	32.5	0.0	0.0	0.0	2169	3800	57.08

Webb Indicator Plot, T-17, Fort Stockton, Texas

This plot was one of two plots that were planted on the Webb Farms 5 miles west of Fort Stockton. The plots, separated by a road and the farm building site had different soil types and textures.

The soils of this plot have been described as Reeves gravelly loam, with numerous phases related as to depth and salinity that formed a soil pattern which was very spotted, and to which shrub growth and survival reacted accordingly. Internal drainage ranged from slow to imperfect with salt concentrations in several areas. Surface drainage was fair. Tilth ranged from fair to cloddy with much coarse gravel on the surface. Irrigation water was conveyed to the area by means of canals and laterals from Leon Springs, a source high in salts.

The plot was planted March 25, 1942, and consisted of 89 rows spaced 30" x 36". Original survival was poor and spotted, due to poor tilth of soil and infestation of Johnson grass. Small areas that appeared alkaline had poor survival. Incidence of disease was light and no injurous insect attacks occurred during the first season. On December 10, 1942 the survival was 42 percent. The plot received five irrigations the first year. The plants at the end of the growing season were quite variable in size but averaged 12" in height and by 14" in spread. No cold injury occurred during the winter of 1942-43 despite a low of 7 degrees F. on January 17, 1943, and another low of 6 degrees on January 26. Examination of the thermograph records disclosed that these lows were very brief, which may explain in part why there was no injury. When the plot was inspected in late March of 1943

the soil was dry on the surface, but moist below 3". It appeared evident that the plants were dormant prior to these low temperatures.

During the growing season of 1943, the general tilth of the plot improved and better control of weeds was effected, resulting in better plant growth. Plants continued to be quite variable in size and few died from disease on the more unfavorable sites. The fourth and last irrigation for the season was on July 31, 1943, but the plants continued to grow until late in the season.

Slight injury to a few of the terminals on about 27 percent of the plants occurred during the winter of 1943-44. Since the lowest temperature of the winter season was only 16 degrees, and occurred on March 29, 1944, after about 30 days of favorable growing temperatures, it would appear that this slight injury was caused at this time. The greatest frequency of injured plants was near, and around the barren areas, much the same as occurred at Ysleta.

Degrees of Injury - Webb Indicator Plot, T-17.- Winter of 1943-44

Degree of Injury in Percent					No. Live Plants	No. Plants Planted	Percent Remaining 1944
1	2	3	4	5			
72.9	27.1	0.0	0.0	0.0	2135	7540	28.4

Webb Indicator Plot, T-19, Fort Stockton, Texas

The soils on the second Webb plot, T-19, have been described as Toyah silty clay loam and Toyah silt loam, with phase variants relating to salinity. The surface drainage is moderate and internal drainage is generally good. Soil tests showed that over the two year period, the subsoil moisture of this plot was always more evenly distributed through the profile than on plot T-17. Water-holding capacity was good and the plants seldom appeared to be under stress.

The plot was planted March 25, 1942. The original stand was better and more evenly distributed than on the first plot, and the plant size was larger and more uniform. The plants were quite free of disease the first season. The plot received five irrigations for the growing season. On December 10, 1942 the survival was 49 percent with an average size of 13" high and 17" wide. The plants appeared quite dormant at this date. No injury occurred during the winter of 1942-43, despite a 6 degree F. Minimum.

Some mortality from root rot occurred during the summer of 1943. The plot received four irrigations during the growing season and the shrub was dormant when examined in early November. Slight injury occurred during the winter of 1943-44. The injured plants were evenly distributed over the plot and did not appear to follow any soil pattern as they did in T-17. As mentioned under T-17 the minimum for the winter was 16 degrees F., which occurred on March 29, 1944, following 30 days of favorable growing weather.

The injuries in the Fort Stockton-Balmorhea area were not greater than may occur in much warmer areas but which are subject to occasional frosts in early spring or late fall. In March of 1944, injury of "2" to "3" intensity occurred at the experimental plantings in the Quemado Valley along the Rio Grande area when a minimum of only 26 degrees F. was reached. These plants were in full spring growth and situated in a frost pocket. Plants 50 yards distant at a higher elevation were uninjured. Similar injuries occurred at Beeville and at the S. C. S. Nursery Plot at San Antonio. Injuries at none of these stations appear to have occurred at the time of the minimum temperature for the winter, but rather at times of sudden drops in temperature while the plants were in an active growth stage. Such minor injuries do not appear to cause more than temporary setback to the plant and the ultimate health and vigor of the plant does not seem to be impaired.

Degrees of Injury - Webb Indicator Plot, T-19 - Winter of 1943-44

Degree of Injury in Percent					No. Live Plants	No. Plants Planted	Percent Remaining 1944
1	2	3	4	5			
75.6	24.4	0.0	0.0	0.0	1723	4960	34.7

Schlegel Indicator Plot, T-21, Fort Stockton, Texas

The Schlegel Indicator plot was located about 3 miles north and a little east of Fort Stockton, Texas on the farm of the late Joseph Schlegel. The soil of the plot has been mapped as Reeves gravelly loam with numerous phases relating to salinity and depth to caliche. The surface was quite friable but very gravelly, and surface drainage was good. Moisture holding capacity of the soil was high and internal drainage, though slow, was adequate. Irrigation water originates at the Comanche Springs and is of fair quality for irrigation, although fairly high in salt content. The growing season is 226 days for the region, with extreme temperature ranges from 114 degrees to minus 7 degrees F.

The plot was planted May, 1942 and consisted of 51 rows about 300 feet long with a spacing of 30" x 36". The planting had good care over the two year period. Cultivation was always good but irrigation was on the light side, both in amounts per application and number of irrigations.

The size of the plants was somewhat below the average of the better plots, but the survival was good, The size of plants probably was influenced both by scanty moisture and shallow soil. Plant size correlated with depth to the underlying caliche which varied from about 12 inches to three or more feet with the largest plants on the deepest soils. Some root rot infestations was responsible for the loss of few plants.

There was no injury during the winter of 1942-43 when temperatures of 6 degrees and 7 degrees were recorded in January. No injury occurred the winter of 1943-44.

The shrub appeared in a more hardened or dormant condition than were the plants at the Webb plots where soil moisture was somewhat higher. This may

account for this difference in injury. Temperatures at the two sites are about the same, although in the winter of 1943-44 the Schlegel plot apparently had a 2 to 3 degree lower minimum than that experienced on the Webb plots.

The Schlegel plot is only about five miles from the nearest native stand of guayule. The soils of the Webb and Schlegel plots are quite typical of the valley soils along the lower rim of the basal slopes into which, however, native guayule never migrated.

Degrees of Injury - Schlegel Indicator Plot - Winter of 1943-44

Degree of Injury in Percent					No. Live Plants	No. Plants Planted	Percent Remaining 1944
1	2	3	4	5			
100.0	0.0	0.0	0.0	0.0	1484	5500	27.0

The Valentine, Balmorhea, and three Fort Stockton plots are discussed not because they sustained any serious amount of injury, but because the plots are near the northern periphery of the plant's natural habitat in a region periodically experiencing temperatures sufficiently cold to kill guayule if these temperatures occurred while the plant was in an active growth stage.

While it is true the soil moisture content was higher in most of the plots where heavy damage occurred, it does not entirely explain the difference in injury. Although the plants on these last five plots were more "dormant" than those where injury was greater, this dormancy was not due entirely to drouth stress. This evidenced by the fact that on all five plots spring growth was resumed prior to spring irrigations or the occurrence of enough rain to be effective. A possible explanation appears to lie in a temperature pattern involving progressively lowering temperatures which bring about a cold induced dormancy in the shrub. Compared with the averages of other years, these two winter temperature patterns seem to have been fairly typical for the area.

Beckham Indicator Plot, T-23, Pecos, Texas

The Beckham Indicator plot was located 12 miles southwest of Pecos, on the W. E. Beckham farm.

The soil is a Reeves clay loam, deep, with several phases relating to alkalinity. For the most part the plot had adequate surface drainage and fair internal drainage, with high moisture holding capacity. The plot was usually in good tilth during the two year period. Irrigation water was furnished from a well with water that was high in salt content.

The plot was planted March 25, 1942, and consisted of 18 rows 750 feet in length with a spacing of 30" x 42". Plant growth was always slow as compared with the better plots in the general region, although irrigation was adequate and the care above average.

There was no injury in the winter of 1942-43 during which a minimum temperature of 10 degrees F. was reported. During the second winter 76 percent of the plants were slightly injured. The night of January 13-14th registered a low of 1 degree F. on a thermograph located at the plot. Only afew of the branches of the injured plants had received terminal injury, generally not to exceed 1/2 to 1". Although the percentage of plants affected was high, the amount of injury to the individual plant was slight. Injury was evenly distributed over the plot with no noticeable patterns.

In May 1944, when the plot was inspected, it had just received the first irrigation of the season, and there was no opportunity to learn the amount of soil moisture present at the end of the winter. However, the plot had been irrigated only two days before inspection and the plants gave every appearance of having been in an active growth stage for at least two weeks indicating there was available water.

Considered from the standpoint of moisture and temperature this plot might have been expected to suffer considerable injury. Actually it was one of the least damaged plots in the region. Possibly the explanation lies in the gradually conditioning temperatures that prevailed in the fall coupled with a certain degree of drouth induced dormancy caused by the salt concentrations in the soil.

Degrees of Injury - Beckham Indicator Plot - Winter of 1943-44

Degree of Injury in Percent					No. Live Plants	No. Plants Planted	Percent Remaining 1944
1	2	3	4	5			
23.5	76.5	0.0	0.0	0.0	1987	5400	36.7

Hubbs Indicator Plot, T-25, Pecos, Texas

The Hubbs Indicator plot was located on the Barney Hubbs farm, four miles west of Pecos. The soil is a Reeves loam, with phases relating to depth of profile and areas of caliche. There were some areas of salt concentrations. Surface drainage was fair, and internal drainage from fair to poor. Irrigation water, with a rather high salt content, originated from a well.

The planting was made on March 24, 1942. The original survival was only 50 percent. The poor stand was probably caused by lack of cultivation and inadequate irrigation. Subsequent mortality was light, but the plants never attained a good size even by the end of the third season.

There was no injury the first winter, when the minimum was 10 degrees F. Minor injury occurred on January 14th of the second winter when the temperature fell to 2 degrees F., U. S. Weather station at Pecos, the same date of the low of one degree F. recorded at the Beckham plot. When examined in early May, the subsoil was fairly moist, but not wet. The type and distribution of injury was similar to that which occurred on the Beckham plot. As with the Beckham plot the shrub was quite dormant in late fall before extremely cold weather began. There was about one inch of spring growth in the areas of deep soils, and very slight growth on the more shallow soils when the plot was examined in May. This was prior to spring irrigation.

Degrees of Injury - Hubbs Indicator Plot - Winter of 1943-44

Degree of Injury in Percent					No. Live Plants	No. Plants Planted	Percent Remaining 1944
1	2	3	4	5			
26.0	74.0	0.0	0.0	0.0	2605	6000	43.4

Tankersley Indicator Plot, T-33, Tankersley, Texas

The Tankersley Indicator plot was located two miles south of Tankersley on the farm of M. D. Bryant. Figure 5b. The plot was in the flood plain of Spring Creek, which is a part of the Concho drainage system that drains a large area of the northern part of the Edwards Plateau. Much of the land in the area is in cultivated crops of cotton, cereals and forage crops. A relatively small percent of the land is irrigated. Precipitation is about 22 inches, growing season 229 days, and elevation 1857 feet. The soil, a Christovol silty clay loam, is friable, deep and well drained with good moisture holding capacity. The plot was about one acre in size and irrigated by a pump that raised water from Spring Creek.

The planting was made April 13 and 14, 1942. There were 70 rows spaced 39" apart, and planted in a modified latin square, with 37 sub-plots spaced 18", 24" and 30" in the row. On the first irrigation many plants in the northeast corner were lost from flooding, which was followed by crown rot. Irrigation was poor and inadequate the first summer with the result that the establishment survival was slightly less than 50 percent. After fall rains began in September the plants doubled in size before they became dormant in the fall. Except for the first three months there was scarcely any disease in the plot. The plant size was small at the end of the first season as compared with the better plots.

During the winter of 1942-43, a minimum temperature of 7 degrees F. caused minor injury. About 3 percent of the plants were killed back to the main stem, and about 2 percent had slight terminal injury.

In the winter of 1943-44 the temperature dropped to one degree F. on January 14. This was at the Bureau Station at San Angelo and it is believed temperatures at the plot were one to two degrees colder. This was the second time that one degree F. has been recorded officially at San Angelo. No lower minimum is on record. Most of the plants were injured, but only slightly, and complete recovery was made with the advent of growth in the spring.

Plentiful subsoil moisture was present throughout the winter season. Compared with the Hubbs and Beckham plots, there appears to have been a little more moisture in the Tankersley plot. All three of these plots were quite dormant in late November. When the injury on these three plots is compared to the State College, Canutillo and Ysleta plots it would appear that the soil moisture factor was secondary in importance to the cooling fall temperatures which conditioned the shrub on the Tankersley, Hubbs, and Beckham plots so the plants were able to withstand 30 degrees of freezing with only slight injury.

Degrees of Injury - Tankersley Indicator Plot - Winter of 1943-44

Degree of Injury in Percent					No. Live Plants	No. Plants Planted	Percent Remaining 1944
1	2	3	4	5			
4.8	95.2	0.0	0.0	0.0	2067	7680	26.9

Lubbock Indicator Plot, T-29, Lubbock, Texas

The Lubbock Indicator plot was located on the Experimental Farm of the Texas Technological College at Lubbock. Figure 5a. This was the most northern of the Indicator Plots in Texas, the area being chosen for the primary purpose of testing the ultimate cold tolerance of guayule. Lubbock lies in the high Plains region and is about 300 miles north and east of Fort Stockton. Elevation is 3242 feet. The greater part of the immediate area is devoted to cultivated crops of cotton, corn, sugar beets and feed crops. Precipitation is about 19 inches. Some supplement water for crops is supplied on a part of the farms from deep wells. The growing season is 205 days.

Though the winters are generally mild with a mean January temperature of 40 degrees F. the region is sometimes subject to drops in temperature due to cold waves coming down from far to the north. Zero minima are not infrequent and a record low of minus 17 degrees F., has been registered. Summer temperatures are warm with an absolute maximum of 108 degrees F., and an average July of 79 degrees F. Temperatures of above 100 degrees F. are not common and those below 15 degrees F. are of very short duration.

The plot was planted on March 23-24, 1942 and consisted of 153 rows about 80 feet long, spaced 30" x 40". The west seven rows were lost during the early part of the first growing season because of weeds and lack of care. The plot was irrigated immediately after planting and again on June 19. After that date, rainfall was the sole source of soil moisture, and the plants were seldom under drouth stress. The survival was 36 percent on December 12, 1942 with an average plant size of 14" high and 16" broad.

Minimum temperatures at the plot during the first winter were zero degrees F. on January 19, 1943, and 7 degrees F. on March 3. On inspection of the plot on March 19, 1943 and it was judged at that time that approximately 35 percent of the plants were injured. No new growth had started, and on about one-third of the plants the leaves were becoming discolored and some were shedding. However, an inspection made on May 26 showed 33.4 percent of the plants dead, with lesser degrees of injury to all except one percent of the plants. Injury was evenly distributed over the plot and showed no patterns of injury as occurred at some of the other plots. The following table gives the degrees of injury for the 1942-43 winter.

Degrees of Injury - Lubbock Indicator Plot - Winter of 1942-43

Degrees of Injury in Percent				
No Injury 1	2	3	4	Dead 5
0.8	33.8	22.8	9.2	33.4

Fig. 5a Lubbock, Texas indicator plot, Jan. 25, 1945. Plants survived minimum temperature of 11° F. without injury winter 1943 - 44.

Fig. 5B Tankersley, Texas guayule indicator plot, July 17, 1944. Plants showed only traces of cold injury at minimum temperature of 1° F. winter 1943-44.

There is some question whether all of the injury was caused by the zero degrees F. temperature in January, or whether part, or possibly most, of the injury may have been due to the 7 degrees F. temperature on March 3. This second low was preceded by two weeks of unusually warm February weather, with a day-time maximum as high as 81 degrees F. accompanied by night minimums above freezing. Interpreted in the light of the second years data, when only slight injury occurred with temperatures of 2 degrees F. at the Hubbs plot and one degree F. at the Beckham and Tankersley Plots, it would appear that there was more likelihood of injury on the March 3 seven degrees low than the zero in January.

No injury was apparent following the winter of 1943-44, during which minima of 12 degrees F. occurred on December 28, and 11 degrees F. on January 8. The soil was very moist in the spring. Rainfall between September 1 and December 31, 1943 was 3-3/4 inches, and, therefore, the plants could not have been dormant due to lack of soil moisture. Dormancy apparently was caused by the gradual approach of cold weather.

During July 1944, shrub was measured to determine how much the injuries of the 1942-43 season had retarded growth. Comparative sizes of plants that underwent different degrees of injury showed:

Degrees of Injury (1942-43)	Summer of 1944	
	Height	Breadth
Very slight or no injury "No. 1 & 2"	24.7"	32.5"
Killed to ground "No. 4"	19.8"	29.3"
Average size (Plot)	22.1"	30.3"

In the light of experience with guayule plantings in the Mesilla, El Paso, and the upper Pecos Valleys the behavior of the plants on the Lubbock plot is interesting. At Lubbock the plant, under high moisture conditions both winters, withstood severe temperatures, especially the first winter with less loss than might have been expected when compared to the New Mexico and Ysleta plots.

The Lubbock plants were from stock that originally came from Cedros, Mexico 600 miles to the south. Whether or not planting material originating in the Fort Stockton native stands would prove more hardy here is not known, but it is a probability. In this connection, it will be recalled that 19 of 20 plants surviving at Woodward, Oklahoma, during the winter of 1943-44, were from seed gathered at Sanderson, Texas. Temperature patterns for fall, winter and spring are similar at Fort Stockton and Lubbock, although it is colder at Lubbock, where the mean January temperature is 7-1/2 degrees lower and the extreme minimum 10 degrees lower. It is interesting to note that the mean January temperature at Fort Stockton is just 7-1/2 degrees colder than the January mean at Cedros. But the extreme minimum at Fort Stockton is about 25 degrees below that minimum at Cedros. Fort Stockton is about equidistant between Lubbock and Cedros, Mexico. It would appear that planting material originating near the northern part of the native range might improve the chances of survival against winter cold.

Of course varieties 406 and 593 may have altered considerably in their hardiness during the 30 years of their domestication.

There is much in the two foregoing paragraphs which is admittedly speculative, but the factors are presented here more to suggest the need of further study than to make definite conclusions. However, it does appear that a strain of guayule might be found, or developed, which would be sufficiently hardy for the High Plains in the region of Lubbock and southward. Here precipitation is sufficient to meet the requirements of guayule. For nearly 100 miles southward, there are extensive land areas of sandy soils, from which there is little run-off, and very similar to the soils of the Lubbock plot. The permeability of these soils make them especially adaptable to guayule culture. This area needs a crop plant such as guayule. Many thousands of acres have been under crop benefit payments during the past several years. In dry years the land suffers from excessive wind blowing. In the years 1934 to 1936 the region was a part of the "Dust Bowl." Extensive planting of such a crop as guayule would do much to stabilize the shifting of the fine sandy soils of this area, and become an economic benefit to the region. Assuming sufficiently hardy strains were available the only critical element would be the initial establishment of the field. If the planting coincided with a dry windy spring it would mean in many cases replanting. On the other hand, once growth had taken place the soil would be safely insured against blowing for the life of the crop and if pollarding was practical the effect would be permanent.

INDICATOR PLOTS PLANTED IN 1943 AND 1944

During 1943 and the spring of 1944, twelve plots were planted in the "critical area" eastward from Tankersley to Waco, primarily for the purpose of testing for winter survival and rainfall tolerance. None of these were irrigated. The rainfall gradually increases from 22 inches annually at San Angelo to 35 inches at Waco. At San Angelo the monthly distribution is very similar to that of the Big Bend, where late fall and winter rainfall is light with the greater portion occurring from May to October. At Waco and through the Central Plains of Texas the rainfall distribution is reversed with the greater portion occurring in late fall, winter and early spring.

The elevation of 1847 feet above sea level at San Angelo gradually diminishes eastward to 424 feet at Waco. The growing season lengthens from 229 days to 250 days. While the mean annual temperature of 66 degrees F. is about the same throughout the area, the patterns of temperature change strikingly to the eastward. At Waco and through the Central Plains the winter months are characterized by frequent sudden drops from growing temperatures to several degrees of frost. Warm periods are often accompanied by rains just prior to freezing weather. See figures 9 and 10. Such phenomena are hazardous to plants which have not attained a sufficient degree of dormancy.

Two of the plots, Lampasas (T-91) and Brownwood (T-93) were not planted until the spring of 1944, and, therefore, served only as short tests for rainfall tolerance.

Eight plantings were made in the spring of 1943, but because they were planted late and succeeding weather was hot and dry several of them, Tankersley (T-33), Wall (T-35), Ballinger (T-37), Manor (T-81), and Waco (T-83) did not survive

the summer. Fair survivals were secured at Burton (T-79), and Johnson City (T-89). The survival was poor at Briggs (T-87). During the following winter these last three plantings experienced varying degrees of injury. Slight injury at Burton with a minimum of 18 degrees F., moderate at Briggs with a minimum of 9 degrees, and severe at Johnson City at 12 degrees. Injury was in inverse ratio to plant dormancy, based on reports covering dormancy in late fall. The injuries at Burton and Briggs appear to have been cause by early frosts. The soil of the Johnson City plot was quite heavy. Warm, rainy weather kept the plants in a lush growing condition up to December 15, 1943 when the temperature dropped to 17 degrees F. The minimum for the winter of 12 degrees F., occurred on January 12, 1944. Inspections following both dates indicate that most, if not all, the injury occurred on the earlier date.

In the fall of 1943, plantings were made at all the foregoing eight plots, plus two others of this group not previously enumerated, at Big Lake (T-27) and Waxahachie (T-85), the most northern in this eastern area. All of these ten plantings were entirely winter-killed during the succeeding winter months. Planting was delayed until late October and November awaiting the fall rains to improve moisture conditions. The plants leafed out well and started a good growth but did not become well-rooted prior to freezing weather. At some of the plots frost bulged many of the plants out of the ground.

On the basis of experience for the winter of 1943-44, it appears that fall plantings in the "critical area" and for at least 50 miles south are too hazardous to be feasible. In the eastern part of the "critical area" where it is necessary to wait for soil moisture from fall rains before planting can begin, the season is usually too late for the plants to establish themselves before freezing weather begins. If rains should occur early enough for plantings to be made in early September, much better results might be obtained.

In the spring of 1943 a small planting of about one-half acre was made by the Texas Branch Agricultural Station at Chillicothe, Texas. An inspection of this planting was made in July of 1944. This station is about 140 miles northeast of Lubbock, and below the rim-rock of the High Plains. The average rainfall here is 25 inches, with a temperature range of from 119 degrees F. to minus 9 degrees F. The weather patterns are quite similar to those of the immediate High Plains to the west, and winter temperatures appear to be greatly influenced by this proximity. No injury occurred despite minima of 12 degrees F. on December 15, 1943, and 11 degrees F. on January 14, 1944. Aside from an irrigation at time of planting, the plants had received no water except rainfall which was less than half the normal amount for the period since planting. The appearance and size of the plants gave evidence of having gone through some drouth stress. This may have been a factor in producing sufficient dormancy to have withstood these minima without injury.

Earlier mention has been made of the private guayule planting of Mrs. R. L. Duke at Dalhart, Texas, at which 31 percent of the plants withstood 17 below zero and zero temperatures during the winters of 1942-43 and 1943-44, respectively. A large part of them also survived the winter of 1944-45 with a minima of 11° F, 5° F and 6° F during December, January and March, respectively.

In contrast to the above experience at Dalhart, all of the plants at Roswell, New Mexico were killed and 93 percent of the plants on the irrigated plot at Artesia by a minimum of 8 degrees F.

While part of the Dalhart plants were killed outright and all showed some injury, the fact that part of them survived temperatures 25 degrees colder than those which killed all the plants at Roswell, and caused heavy losses at Artesia, Canutillo and Ysleta appears of considerable significance.

Although observations over a three year period disclosed that there were some differences in cold tolerance among plants of the same strains, such as 406 and 593, these differences appeared to be rather slight when the identical plants were observed on succeeding years. Since the plants at Dalhart were strain 593 it does not appear probable that they were as a whole any more cold tolerant genetically than the plants at the other stations. It is only logical to conclude that the main reason for high survival was not so much genetic as environmental.

The greater cold tolerance of the plants could not have been due to dormancy brought on by dryness of the soil because twelve inches of rain fell during August, September and October -- 4.66 inches of it in October just prior to the beginning of severe freezing temperatures. With this amount of rain the soil must have been near saturation. In respect to soil moisture it appears that it should have been greater here than at the Roswell and Artesia plots.

Continued cold weather commonly causes plants to go dormant. A study of the weather records for Dalhart shows that weather condition was favorable for such development. Both the extreme high and low temperatures for the last ten days of October were below the growing temperatures, with an average maximum of 57 degrees F. and an average minimum of 21 degrees F. It has been found that periods of cool temperatures ranging from 60 degrees F. to freezing or below bring on dormancy of guayule quite rapidly, so the weather during latter part of October at Dalhart was cold enough to have started the plants into dormancy. November continued with temperatures well below the degree needed for active growth; and December and January were progressively colder. See figure 8. Temperatures through December to March indicate that the ground must have been frozen for the period to well below the root crowns despite the fact that there was a 5 inch snow cover for a part of the period. Temperatures occur in much the same pattern year after year, with little variation except in intensity.

It, therefore, appears that the important factor contributing to the high winter survival under very low temperature lies in progressively lowering temperatures in late fall and early winter, and, also, the continuance of below growing temperatures throughout the winter season. The pattern of fall and winter temperatures which prevailed at Dalhart from 1942 to 1945, and which appears to be the pattern generally for most years in this area, resulted in a high survival when the intensity of the cold is taken into account.

While more and better data are needed on the other factors such as soil moisture, soil temperature, and some method of determining the degree of dormancy, it appears that soil moisture per se is not a hazard to survival of guayule under low temperatures if the plant is really dormant. As indicated on the Dalhart shrub certain patterns of winter temperature appear to produce dormancy sufficiently complete for survival at very low temperatures, despite the presence of an abundance of soil moisture.

FROST INJURY DATA -- NEW MEXICO AND TEXAS INDICATOR PLOTS
DEGREES OF INJURY GIVEN PERCENTAGES

PLOT NO.	LOCATION	WINTER 1942-43					MINIMA TEMP.	WINTER 1943-44					MINIMA TEMP.	LOWEST TEMP. RECORDED
		1	2	3	4	5		1	2	3	4	5		
N-1	Deming	——	——	——	——	——	15° F.	6.2	75.5	18.3	0.0	0.0	8° F.	- 7° F.
N-5 B5	State College	——	——	——	——	——	13°	4.6	18.9	34.2	36.9	5.4	9°	- 8°
D4	" "	——	——	——	——	——	13°	0.5	37.1	44.5	13.9	4.0	9°	- 8°
N-10	Roswell	0.0	0.0	0.0	3.4	96.6*	5°					100.0	8°	-29°
N-15 Dr	Artesia	25.5	43.8	14.3	8.3	7.1**	6°	0.0	1.1	12.5	40.5	45.9	8°	-35°
Ir	"						6°	0.0	0.0	1.9	4.8	93.2	8°	-35°
N-20	Loving	——	——	——	——	——	12°	27.4	61.9	10.7	0.0	0.0	9°	-17°
T-1	Canutillo	——	——	——	——	——	14°	0.0	24.4	26.0	44.0	5.6	10°	- 5°
T-3	Ysleta	——	——	——	——	——	14°	0.0	31.2	37.9	22.4	8.5	11°	- 5°
T-5	Valentine	——	——	——	——	——		26.7	44.8	28.5	0.0	0.0		
T-13	Balmorhea	——	——	——	——	——	10°	67.5	32.5	0.0	0.0	0.0	17°	- 9°
T-17	Webb	——	——	——	——	——	6°	72.9	27.1	0.0	0.0	0.0	16°	- 7°
T-19	Webb	——	——	——	——	——	6°	75.6	24.4	0.0	0.0	0.0	16°	- 7°
T-21	Schlegel	——	——	——	——	——	6°	100.0	0.0	0.0	0.0	0.0	16°	- 7°
T-23	Beckham	——	——	——	——	——	10°	23.5	76.5	0.0	0.0	0.0	1°	-10°
T-25	Hubbs	——	——	——	——	——	10°	26.0	74.0	0.0	0.0	0.0	2°	-10°
T-29	Lubbock	0.8	33.8	22.8	9.2	33.4	7°	4.8	95.2	0.0	0.0	0.0	1°	1°
T-33	Tankersley	95.0	2.0	0.0	3.0	0.0	0°	100.0	0.0	0.0	0.0	0.0	11°	-17°

1943 SPRING AND FALL PLANTING

T-27	Big Lake	First planted in fall. Fall planting 100% winter-kill		
T-33	Tankersley	Spring Planting - Survival poor - Plowed up in fall. Fall planting 100% winter-kill		
T-35	Wall	" " - 13% survival - Plowed up in fall. Fall planting 100% winter-kill	1°	1°
T-37	Ballinger	" " - 6% " " " " " " " " " "		- 2°
T-79	Burton	28.2 71.8 0.0 0.0 0.0	15°	- 2°
T-81	Manor	Spring planting - Survival poor - Plowed up in fall. Fall planting 100% winter-kill		- 1°
T-83	Waco	" " " " " " " " " " " " " " " "	18°	- 5°
T-85	Waxahachie	First planted in fall. Fall planting 100% winter-kill		- 9°
T-87	Briggs	0.0 65.8 34.2 0.0 0.0	9°	- 3°
T-89	Johnson City	0.0 6.2 31.1 44.6 18.0	12°	- 6°
T-91	Lampasas	Not planted until the spring of 1944		- 7°
T-93	Brownwood	" " " " " " "		- 3°

Legion for Degrees of Injury: 1 - No injury or too minute to be readily observed, 2 - Slight - injury of terminals to 2-1/2 inches, 3 - Moderate - injury to as much as 2/3 of plant volume, 4 - Severe - all aerial portions of plant killed, 5 - Complete - beyond recovery.

* Loss largely due to damage by stock.

** Half of loss due to disease.

SOVIET INVESTIGATIONS

Since about 1925 the Soviet have been planting guayule and investigating the plant as a possible source of rubber. Such reports as are available disclose that considerable progress has been made in the selection and development of adaptable varieties or strains and in the choice of areas suitable for the culture of guayule as a crop. Adaptability to cold temperatures has been one of their main problems and their reports tend to dwell on the subject.

After many exploratory plantings had been made over a wide area, particularly in the region of the Trans-Caucasus, the Margushevan Experiment Station was established in 1930 and 15 plantings were made in the wide inter-mountain valley which lies between the greater and lesser Caucasus. (2). The region constitutes the USSR Republic of Azerbaidjan and is watered by the Kura and Arax Rivers which flow into the Caspian Sea.

Rainfall and temperatures over the region as a whole are quite variable, but there are many areas in which both rainfall and temperature are well within the limits of successful guayule culture. In the zone chosen for guayule growing, the mean annual temperature ranges from 56 degrees to 60 degrees F., the July means from 79 degrees to 84 degrees F. and the January means from 34 degrees to 36 degrees F., with absolute minima from 2 degrees to 13 degrees F. The annual precipitation ranges from 14.5 to 15.5 inches. (8).

Through years of trial and error the Soviet have established a rather hard and fast rule to which they adhere as nearly as possible when chosing areas adaptable for the cultivation of guayule. The standard is an area with a mean annual temperature of 54 degrees to 57 degrees F., precipitation for the period of November to January not exceeding 1.5 to 2.5 inches and absolute minima ranging from 14 degrees to 9 degrees F.

Experience in the upper Rio Grande and middle Pecos Valleys makes it appear that the behavior of guayule in these valleys is about the same as in Azerbaidjan as both have patterns of winter temperature differing from those of the native habitat of guayule.

Great stress is laid on soil-moisture and temperature relationships. Krashennikov (5) sums up his observations in the following statement. "Fundamental causes of loss of guayule during the winter period are high soil moisture and frosts. Experiments have established that at a soil moisture of 40 to 45 percent of the full moisture-holding capacity, guayule endures shorttime frosts of zero to minus 4 degrees F.; at soil moisture of 60 percent is damaged to some degree by frosts of 9 degrees to 5 degrees F., at moisture of 80 percent is damaged by frosts of 18 degrees to 14 degrees F., and freezes badly at 9 degrees to 5 degrees F."

But despite their usual meticulous care in making observations, the Soviet writers make no attempt to explain wide difference in degree of injury at two or more stations where soil moisture and temperatures were comparable. For instance, during the winter of 1931-32 the planting of Kirovabad suffered a mortality of 75 percent with a minimum of 12 degrees F. and a soil moisture

of 13.4 percent in December, wheras at Geokchai the mortality was only 20 percent with a soil moisture of 14.6 percent and a minimum 11.5 degrees F. for the same month. Since the same varieties were used at each station, the discrepancy cannot be attributed to varietal differences.

The Soviet plant breeders have developed, through the processes of selection and plant breeding, two or three varieties which appear from their own statistics to be more cold tolerant than others. "Pioneer Karabakh" is reported to be very cold tolerant, but sufficient data are not available to compare it to ours.

CONCLUSIONS

The three years observation of guayule tolerance to cold has done little more than show trends. The subject deserves more intensive treatment and it is hoped that work by a qualified research agency can be undertaken so that should an emergency again arise more dependable information would be available on the areas in which guayule could be planted with a fair assurance of success.

Qualifying them as being the most generalized conclusions it would appear that:

1. Degree of injury is in inverse ratio to degree of dormancy.

2. Varieties 406 and 593 when quite dormant can withstand zero degrees F. with little or no injury. There is no hardiness differential in the two varieties.

3. High soil moisture does not appear to a primary hazard if the plant is dormant.

4. At Dalhart, Texas 31 percent of a private planting survived a minimum temperature of minus 17 degrees in a soil that was very high in moisture.

5. An important factor in winter survival appears to lie in the temperature pattern that exists in late fall and early winter;i.e. a gradual and progressive onset of lowering temperatures provide a high degree of protection regardless of the presence of high soil moisture.

6. Especially hazardous areas are those subject to "winter warm spells" with temperatures high enough to induce plant growth and which in turn are followed by freezing temperatures.

7. What would appear to give the plant the greatest insurance against winter injury is a climate pattern in which a fall dry period coincides with a progressive and gradual temperature decline.

8. With comparable temperatures and variable soil moistures the degree of injury appears in direct ratio to the amount of moisture.

9. It would appear that the minimum temperature at which injury occurs is a fluctuating point whose value is determined by the fall and winter weather pattern.

10. In irrigated areas where there is little or no rainfall in the late summer or fall, dormancy may be controlled by withholding irrigation sufficiently to induce dormancy from drouth and thus protect the plant from injury by cold. In any event, where temperatures fluctuate rapidly between growing temperatures to as low as 15 degrees F., some injury should be anticipated; and if it falls from high temperatures to 15 degrees F. or lower, heavy to total loss may occur.

The Mesilla and middle Pecos Valleys while characterized by fall drouths nevertheless are subject to short intervals in which growth takes place when moisture is present. When these periods are followed by abrupt drops to freezing temperatures (which is usually the case) injury occurs.

In that portion of the High Plains, Fort Stockton to Lubbock, a fall drouth normally occurs in the southern part but not in the northern. However, the normal fall and winter temperature pattern is similar throughout, with gradually declining fall temperatures, and winters with temperatures which normally are never high enough to induce active vegetative growth.

In the eastern area in which guayule test plots were established, a Central Plains pattern of climate is found. Abundant moisture is present during the fall and winter months and temperatures are usually high enough to activate plant growth but are frequently interrupted by short intervals of freezing temperatures which can cause severe injury.

Figure 6 - PATTERN OF WINTER TEMPERATURE

FOR

UPPER RIO GRANDE VALLEY 1943-44

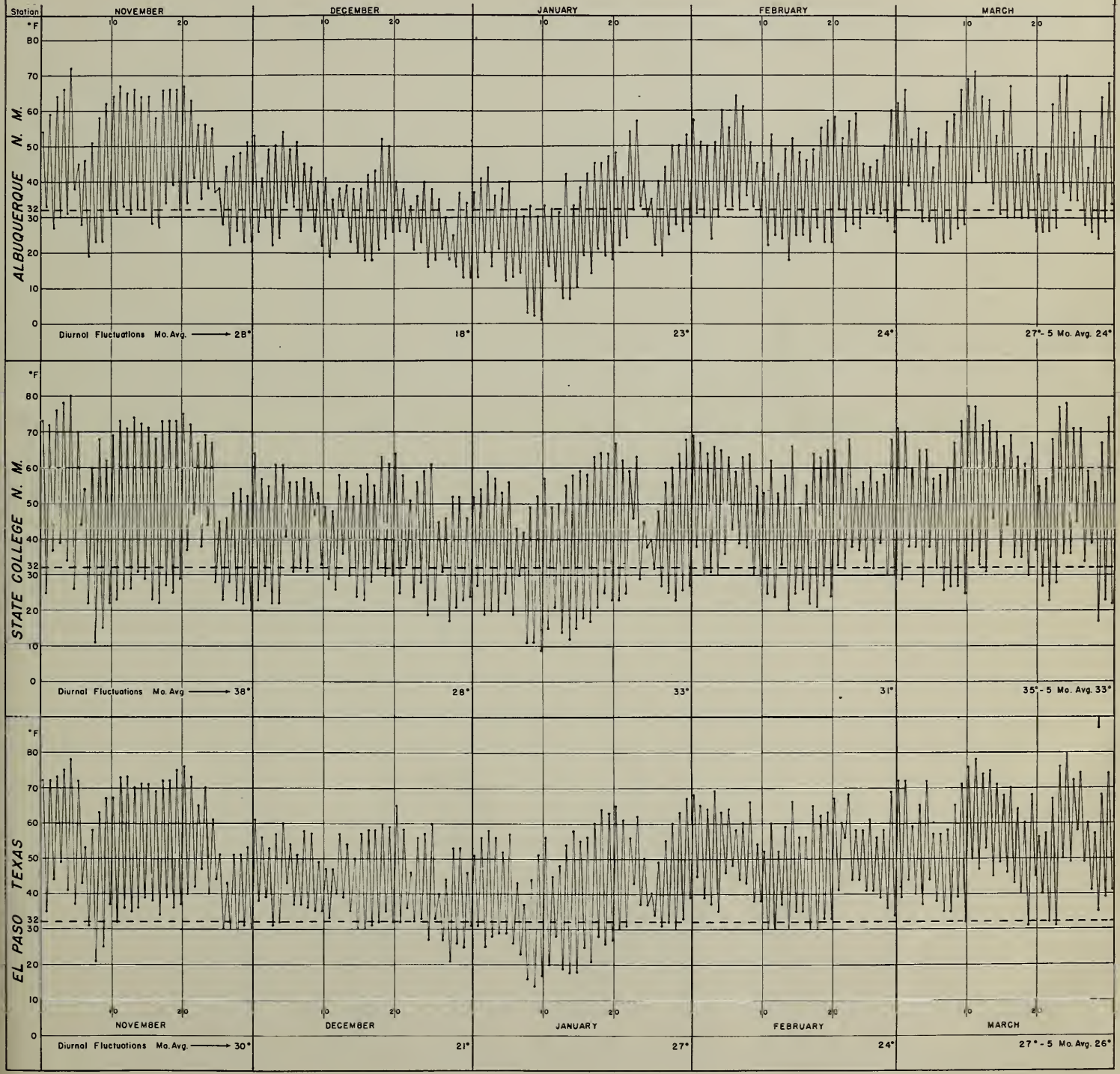


Figure 7 - PATTERN OF WINTER TEMPERATURE

FOR

MIDDLE PECOS VALLEY STATIONS 1943-44

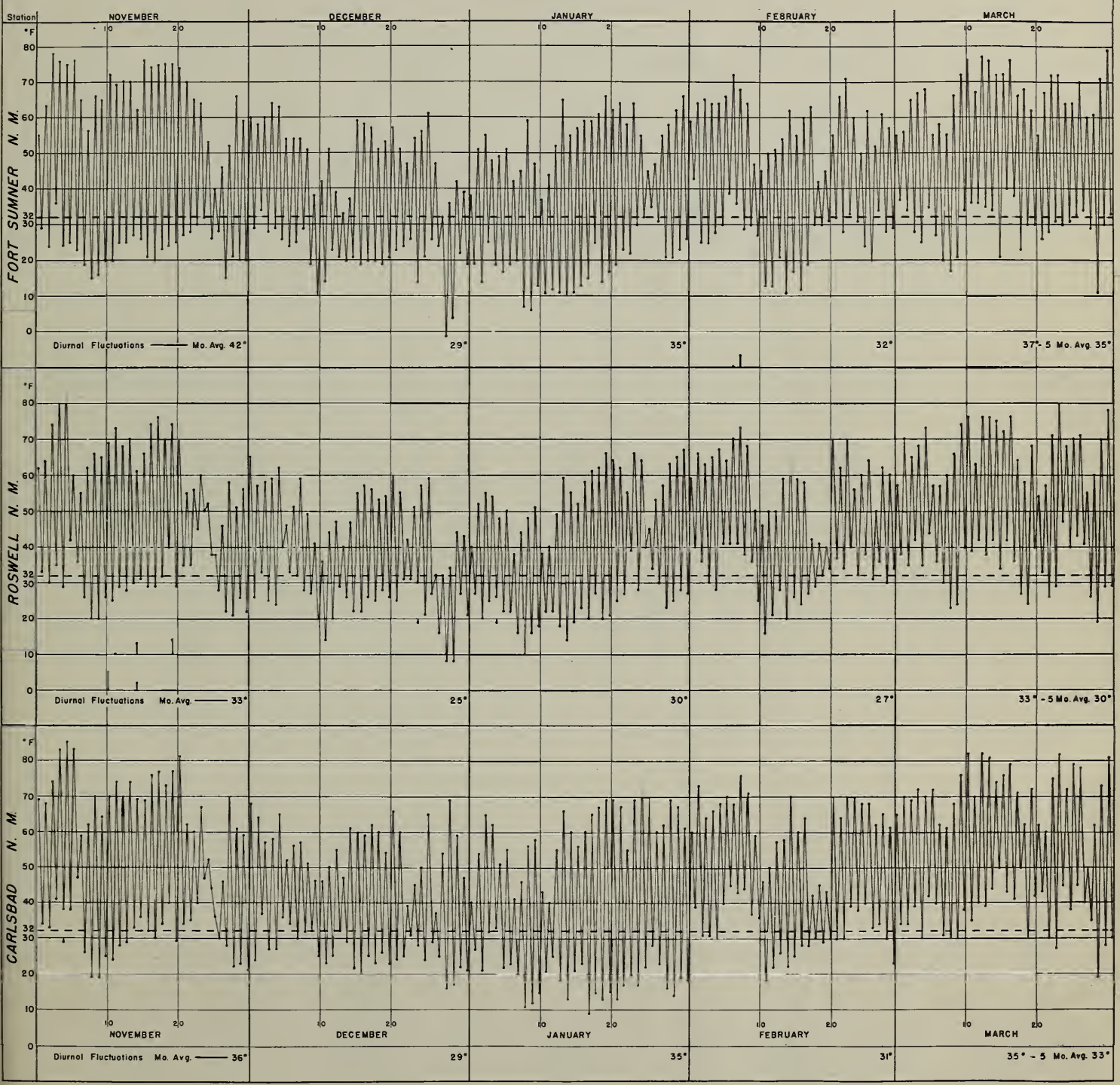


Figure 8 - PATTERN OF WINTER TEMPERATURE

FOR

HIGH PLAINS STATIONS 1942-43

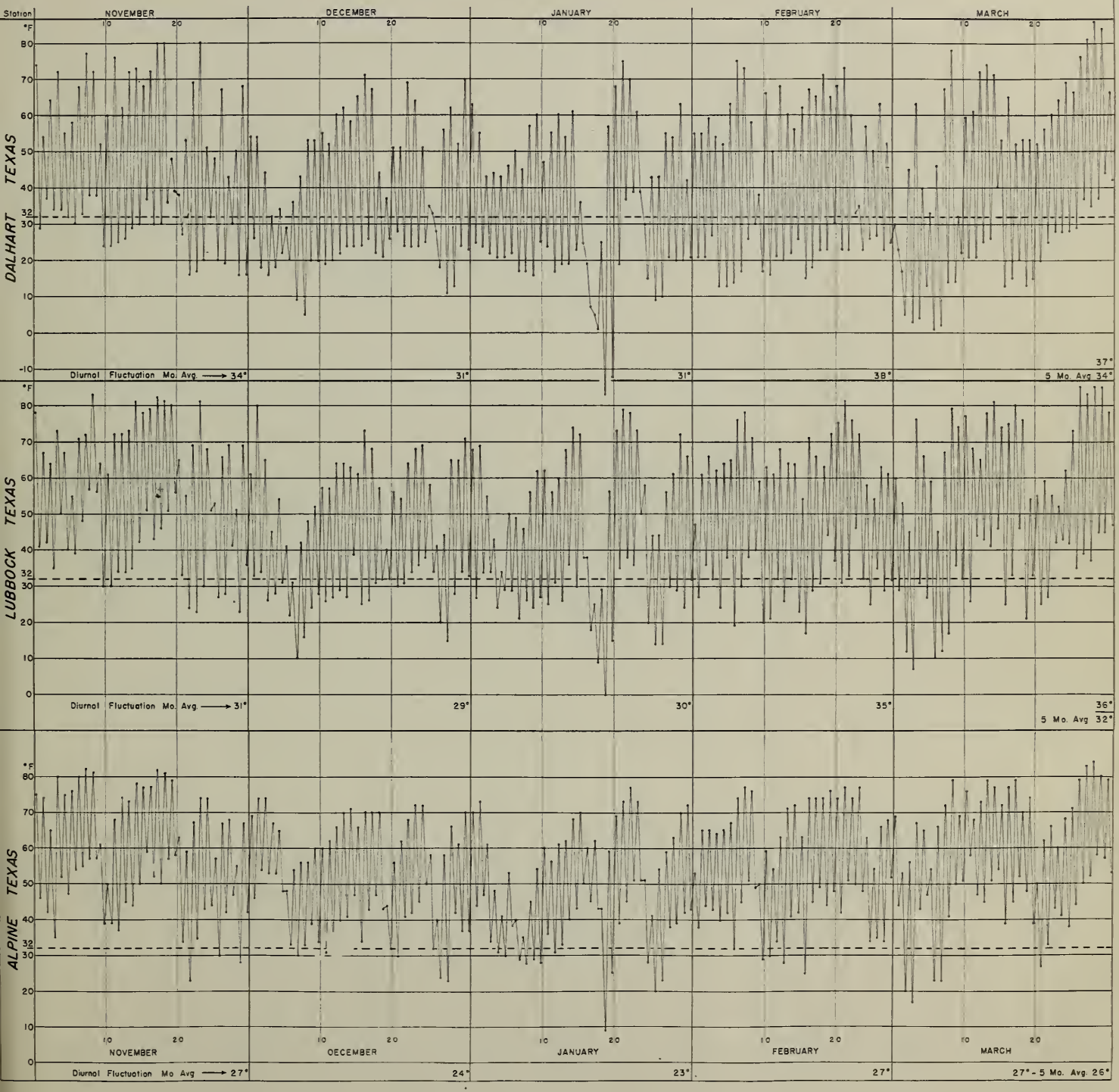


Figure 9 - PATTERN OF WINTER TEMPERATURE

FOR

HIGH PLAINS STATIONS 1943-44

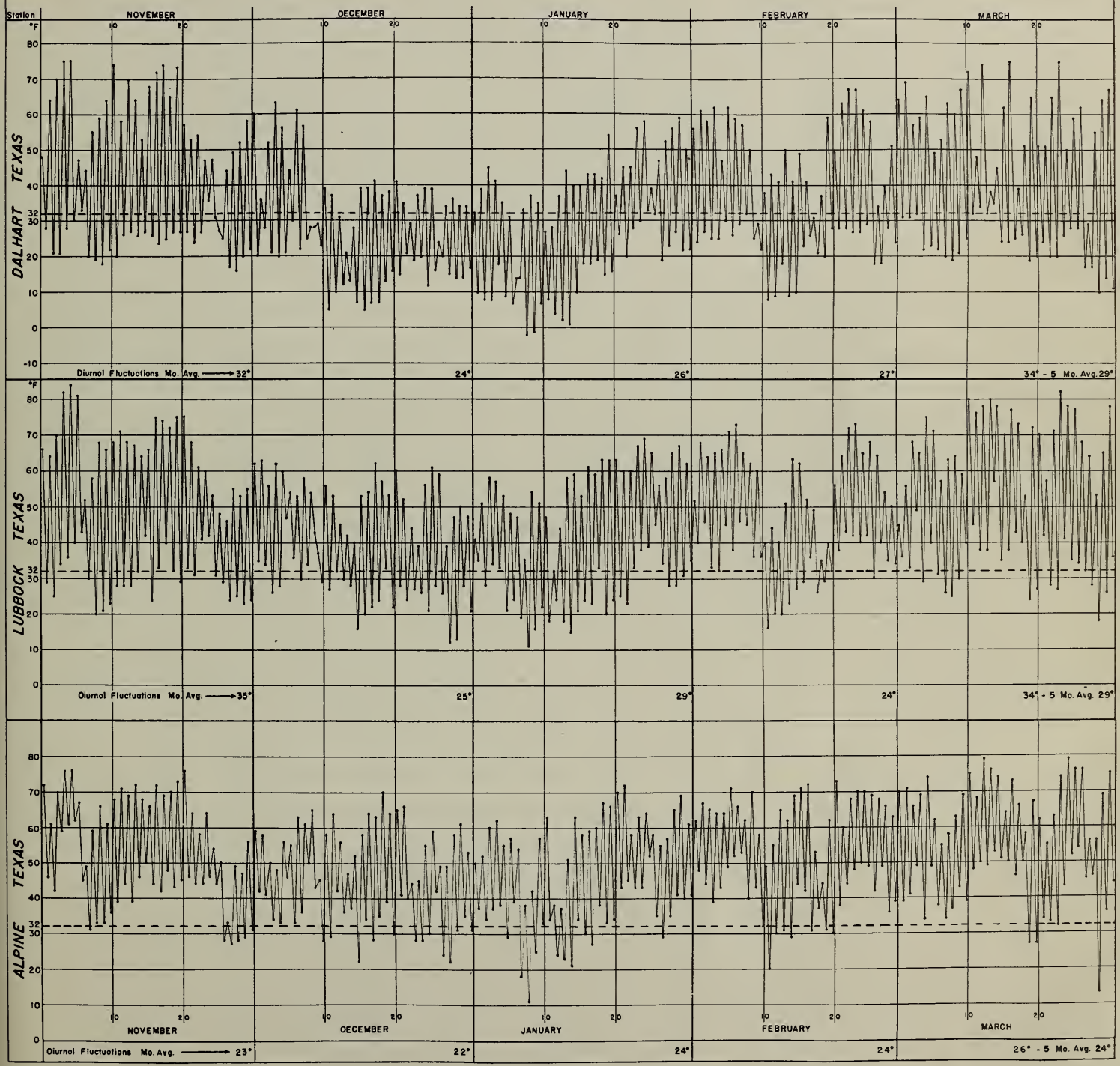
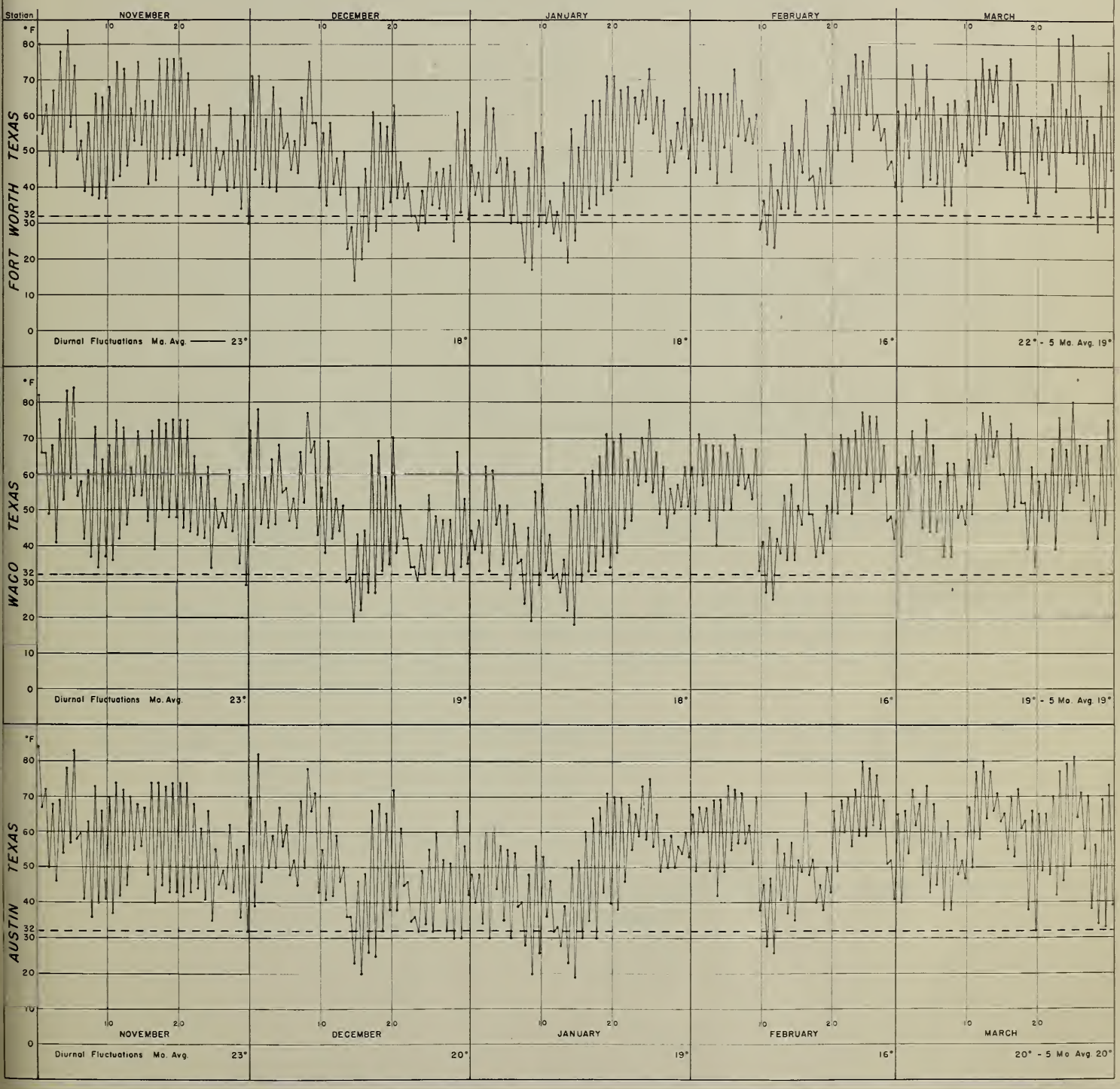


Figure 10 - PATTERN OF WINTER TEMPERATURE
FOR
TEXAS CENTRAL PLAIN STATIONS 1943-44



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